VOLUME LXI NUMBER 4 WHOLE 537

SCHOOL SCIENCE AND MATHEMATICS

APRIL 1961

School Science and Mathematics

A Journal for All Science and Mathematics Teachers

All matter for publication, including books for review, should be addressed to the editor. Payments and all matter relating to subscriptions, change of address, etc. should be sent to the business manager.

Second-class postage paid at Menasha, Wisconsin and at additional mailing offices. Published Monthly except July, August and September at Curtis Reed Plaza, Menasha, Wis. PRICE: Six dollars a year; foreign countries $6.50; current single copies 75 cents.

Contents of previous issues may be found in the Educational Index to Periodicals.

Copyright 1961, by the Central Association of Science and Mathematics Teachers, Inc.

Printed in the United States of America

GEORGE G. MALLINSON
Editor
Western Michigan University
Kalamazoo, Mich.

JACQUELINE MALLINSON
Assistant Editor
Kalamazoo, Mich.

LUTHER SHETLER
Business Manager
P.O. Box 108, Bluffton, Ohio

Editorial Offices: 535 Kendall Avenue, Kalamazoo, Mich.

DEPARTMENTAL EDITORS

CHEMISTRY—Gerald Osborn
Western Michigan University, Kalamazoo, Mich.

ELEMENTARY SCIENCE—Ila Podendorf
University of Chicago Lab. School
Chicago, Ill.

GENERAL SCIENCE—Hanor A. Webb
245 Blue Hills Dr., Nashville, Tenn.

MATHEMATICS—Alice M. Hach
Ann Arbor Public Schools
Ann Arbor, Mich.

—Irvin Brune
Iowa State College
Cedar Falls, Iowa

—Cecil B. Read
University of Wichita, Wichita, Kan.

MATHEMATICS PROBLEMS—Margaret F. Willerding
San Diego State College, San Diego, Calif.

PHYSICS—J. Bryce Lockwood
Highland Park Junior College
Highland Park, Mich.

Collecting Nets

Turtox manufactures more than fifty types of field collecting nets for air and aquatic use. These nets, as well as many types of replacement net bags, are illustrated and described in the current Turtox Biology Catalog No. 62.

TURTOX PRODUCTS

GENERAL BIOLOGICAL SUPPLY HOUSE
Incorporated
8200 SOUTH HOYNE AVENUE
CHICAGO 20, ILLINOIS
The Sign of the Turtox Pledges
Absolute Satisfaction

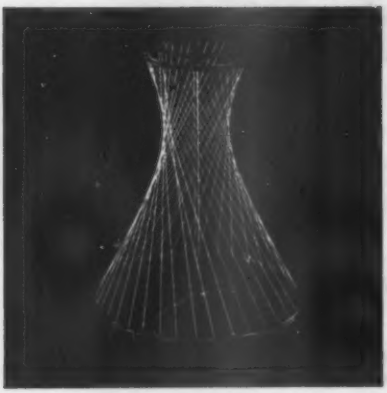
Ingenious new math teaching aids

SCIENCE MATERIALS CENTER "Portable Laboratories" for demonstration and pupil activity, grades 7-12

- **Dramatize basic concepts in solid geometry, logic and mathematical functions**
- **Accompanied by expertly written, highly illustrated instruction books that pupils really can read**

SOLID SHAPES "PORTABLE LAB"

Simple solids such as prisms and pyramids, the five regular solids and complex semi-regular polyhedra can be put together in a matter of minutes with this vividly-colored set. Folding flaps on the sturdy cardboard panels lock with rubber bands. Detailed instruction manual, with more than 100 illustrations, explains how to make 30 different polyhedra and shows how *Euler's Theorem* applies to these shapes. Reading level is at Grade 6 up, with simple activities for Grades 6 to 9 and more advanced activities for students of plane and solid geometry. **$6.95.**



SPACE GEOMETRICS "PORTABLE LAB"

More than 58 kinds of mathematical forms and patterns are brought to brilliant life with different-colored fluorescent elastic cords laced between corners and rings. Two- and three-dimensional models are easily constructed to demonstrate such fundamental concepts as vortex, convergent lines, coordinate planes, axes and locus. Special *Roto-Spacer* quickly changes a cylindrical surface into hyperboloids of revolution and then into conic sections. Contents of kit: 2 perforated Space Corners; 8 Rings (specially formed metal with diameters ranging from 4 to 8 inches); 1 Roto-Spacer; 6 spools of fluorescent elastic string; 48-page, 4-color manual, dozens of illustrations. **$12.95.** (Separately available: *Space Spider*, $2.95; *Space Rings*, $4.95.)

"PORTABLE LABS" IN COMPUTER THEORY

BRAINIAC K-30 COMPUTER CIRCUITS

Provides excellent demonstration material in the mathematics of logic. One circuit guesses age from a series of yes-no questions. A quiz-scoring circuit automatically tallies right and wrong answers. For advanced projects, pupils can pose their own logical problems and work out circuits to solve them. 80-page assembly and instruction manual, with 50 large circuit diagrams. **$18.95.**

CALCULO ANALOG COMPUTER

An excellent demonstration of an electric slide rule that multiplies, divides, finds powers and roots and solves problems dealing with a number of formulas (compound interest, growth, etc.). 36-page instruction booklet provides complete assembly instructions and shows how to mark off other functions on blank dials that are provided. **$16.95.**

(Coming soon: PROBABILITY AND STATISTICS "PORTABLE LAB," designed by Edmund C. Berkeley, $14.95.)

Quantity discounts available on all of above items. For orders, information, and FREE catalog of tested, age-graded science-teaching aids, write to Dept. M-171

SCIENCE MATERIALS CENTER, 59 Fourth Avenue, New York 3, N. Y.

WHAT IS THE ASTRONOMICAL LOCATOR?

It demonstrates how the apparent sun on the opposite side of the orbit determines the location of the earth in space.

The Locator explains problems like the above and many more. This instrument is a new kind of sundial transparent to show the time in north latitude whether the sun is north or south of the equator.

By turning the large 12-inch disk with its apparent sun marker to any hour on the small dial one can see readily what part of the sky is currently overhead and which constellations along the ecliptic are in view at night.

OF TIME, SPACE, AND THE LOCATOR, the booklet included in the price of the Locator contains many original diagrams demonstrating difficult concepts.

Detailed pictured assembly provided.

PREMIER PLASTICS CORPORATION
204 W. Washington St.
Milwaukee 4, Wis.

No. 607

Please send the following:

☐ LOCATOR with booklet, $4.00 Postpaid
☐ Booklet, $ 1.00 Postpaid
OF TIME, SPACE, AND THE LOCATOR
☐ Free descriptive literature

School .....
Position .....
Name .....
Address .....
City ..... Zone ..... State .....

CONTENTS FOR APRIL, 1961

What Does the Future Hold for Junior High Science?—*Norman D. Anderson* and *Walter R. Brown* 239

Some Psychological Principles Underlying Mathematics Instruction—*H. Van Engen* 242

The AAAS Feasibility Study on Science in the Elementary and Junior High Schools—*John R. Mayor* 251

The Current Status of Science Education in the Elementary Schools—*Jacqueline Mallinson* 252

Science for Grades Seven, Eight and Nine—*Abraham S. Fischler* 271

NSF Summer Institutes for High School Students 286

Supervision of Science and Mathematics—*James W. Busch* 297

Supervision of Science and Mathematics—*Haron J. Battle* 302

Scientific Research—A Hobby?—*Morris Goran* 309

Mathematics Applied to a Common Custodial Problem—*Cecil B. Read* and *Donald F. Cowgill* 310

Problem Department—*Margaret F. Willerding* 311

Books and Teaching Aids Received 314

Book Reviews 316

The Americana never fails either of them.

With equal clarity and total satisfaction, The *AMERICANA* speaks to the junior high school student and the most advanced scholar. To her it says, "April 4, 1949 . . . the Brussels powers, United States, Canada, Portugal, Denmark, Norway, Italy, Iceland . . . Senator Vandenberg . . . President Truman . . ." To him it says, "Yalta . . . Potsdam . . . Soviet techniques of internal pressure . . . Mutual security . . ." Each needs clarity and absolute accuracy. That's why both turn to the encyclopedia which completely serves the lifelong needs of every scholar. The *AMERICANA's* great 1961 edition fittingly marks its 132nd year of growth. Since 1956 alone, continuous revision has resulted in: the complete rewriting, revising and resetting of over 20,000 pages; all new bleed maps of striking design and considerably larger scale; more than 6,500 new pictures making a total of 15,000 illustrations; 14% larger type for every one of its 59,000 articles; heavier, whiter paper throughout all of its 30 volumes.

The Encyclopedia **AMERICANA**

THE MODERN AMERICAN ENCYCLOPEDIA
INTERNATIONAL IN SCOPE ©AMERICANA CORPORATION

THE AMERICANA CORPORATION A DIVISION OF GROLIER INCORPORATED 575 LEXINGTON AVENUE, NEW YORK 22, N. Y.

NO OTHER Electrostatic Generator Provides ANY Of these Features

- *Universal Motor* Drive, designed for operation on 110-volt A.C., or 110-volt D.C.
- *Electronic* Safety Valve, to protect the motor against a random high-voltage surge.
- *Removable* Discharge Ball, which the demonstrator may use as a wand.
- *Flat Top* Discharge Terminal (with built-in jack) to receive various electrostatic accessories.
- *Endless* Charge-Carrying Belt, of pure latex, which may be driven at high speed without "bumping."

ALL of the foregoing features are *standard equipment* in CamboscO Genatron No. 61-705.

~

In addition, CamboscO Genatron No. 61-708 incorporates a built-in speed control, to facilitate demonstrations requiring less than maximum voltage.

~

The Output, of either model of the CamboscO Genatron, ranges from a guaranteed minimum of 250,000 volts to a maximum, under ideal conditions, of 400,000 volts. Yet, because the current is measured in microamperes, and the discharge duration is a matter of microseconds, no hazard whatever is involved for operator or observer.

- *May we tell you more?*

CAMBOSCO GENATRON 61-705

CAMBOSCO GENATRON 61-708

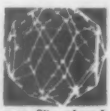
CAMBOSCO SCIENTIFIC CO.
37 ANTWERP ST. • BRIGHTON STATION
BOSTON, MASS., U.S.A.

EDMUND INSTRUCTIVES

• To promote interest in Mathematical outside activities on the part of pupils, we are including an eight page section on Mathematics—on the importance of Mathematics to individuals and presenting learning aids—in our catalog which has a circulation of over a half a million so that the importance of Mathematics is brought to the attention of many people.

Also, we offer dozens of low-cost Scientific items—for learning, teaching, experimentation. Watch our advertisements for new items. We will greatly appreciate it if you as a teacher will recommend us to pupils interested in learning aids, books, etc.

D-STIX CONSTRUCTION KITS



You can increase interest in geometry and teach it better by using D-Stix. Solid geometry is fun for pupils when you show them actual visualizations of regular polyhedrons, geometric figures from triangules and cubes through such multiple sided figures as icosahedrons, dodecahedrons, etc. 220 pieces, 5, 6 and 8 sleeve connectors, 2", 3", 4", 5", 6" and 8" colored D-Stix

Stock No. 70,209-SK .....$3.00 Postpaid
370 pieces, including 5, 6 and 8 sleeve connectors, 2", 3", 4", 5", 6", 8", 10" and 12" D-Stix in colors.
Stock No. 70,210-SK .....$5.00 Postpaid

452 pieces, includes all items in 70,210 above, plus long unpainted D-Stix for use in making your own designs.
Stock No. 70,211-SK .....$7.00 Postpaid

WORLD-TIME INSTRUCTIVE

Why do we have differences in time occurring simultaneously at different points around the world? Why must we have an international date line to adjust these differences? Teachers who have found their classes have difficulty understanding the answers to these questions will discover that the WORLD-TIME INSTRUCTIVE is a valuable teaching device. The logic of world time is made visual and lucid even to the slower student when a demonstration is given with this new instructive. The impact is much greater than when only a globe is used for the explanation. Printed on durable laminated sheets that can be easily wiped clean.

Stock No. 60,140-SK .....$3.00 Postpaid

NEW! GRAPH RUBBER STAMP

Real time and labor saver for math teachers. If your tests require graph backgrounds—no need to attach separate sheets of graph paper and worry about keeping them straight. Simply stamp a graph pattern, 3" square as needed on each paper. Grading graph problems then becomes 100% easier. Stamps are 3" square overall—2 different patterns.

Stock No. 50,355-SK (100 blocks) .....$3.00 Pstpd.
Stock No. 50,351-SK (16 blocks) .....$3.00 Pstpd.
Polar Coordinate Graph Stamp—3" Diam.
Stock No. 50,359-SK .....$3.00 Pstpd.

LARGE-SIZE OPAQUE PROJECTOR

Ideal for enlarging and projecting drawings, photo's, formulas, etc. for classroom study. Low-cost unit takes any opaque copy up to 6" x 6"—projects image 3½ feet square at 6 feet, 7⅛ feet square at 12 feet—in true color, exact proportions. Broadens use of visual aids. Increases class interest. Projector is 11½" high, 13¼" wide, 9" front to back, pressed steel in black wrinkle finish, bakelite handle. Lenses are 2 plano-convex, 2¼" diameter, mounted in 5¼" barrel. Uses two 200-watt bulbs, not included. Complete with slide platform to hold illustrations, 6-ft. electric cord, heat resist. plate glass mirror.

Stock No. 80,066-SK .....$42.00 Postpaid

ANALOG COMPUTER KIT

Ideal introduction to the increasingly important electronic computer field. For bright students, or anyone interested in this new science. Demonstrates basic analog computing principles—can be used for multiplication, division, powers, roots, log operations, trig problems, physics formulae, electricity and magnetism problems. Easily assembled with screwdriver and pliers. Operates on 2 flashlight batteries. Electric meter and 3 potentiometers are mounted on die-cut box. Answer is indicated on dial. Computer is 20" long, 9" wide, 2" deep.

Stock No. 70,341-SK .....$14.95 Postpaid

MAGNETS—5¢ EACH

INEXPENSIVE CERAMIC MAGNETS—These are strong durable magnets ¾" x 1" and 3/16" thick with 3/16" hole in center. Excellent for classroom distribution. Also use for making magnetic visual aids for use on magnetic chalk boards, etc.

Stock No. 40,428-SK Package of 12 $1.00 Ppd.
Stock No. 60,142-SK Package of 100 $5.00 Ppd.
U-SHAPED MAGNETS—Large 5½" long poles ⅞" x ¼" with 2¼" between poles. Keeper included.
Stock No. 60,132-SK .....$1.50 Ppd.
BAR MAGNETS—Nicely painted, powerful Alnico magnets 6" long, 1¼" x ⅜".
Stock No. 40,421-SK .....$1.60 Ppd.

NEW! JUST OFF PRESS!

Write for

FREE EDUCATIONAL CATALOG—"SK"

96 Pages . . . New, Useful Instructives

Dozens of new devices for teaching science, mathematics, astronomy, physics, etc. Scores of new kits and materials for Science Fair and other science projects! That's what you'll find in Edmund's new 96-page Educational Catalog for 1961. It's literally packed with new and exclusive math-and-science concepts developed by Edmund Scientific Co. and now available to schools for the first time.

Look at the partial listing of its fascinating contents: low-cost models for teaching basic mechanical and physical principles; actual working models of communication devices that can be set up, taken apart, and reassembled by students; a whole line of new science kits to spark science projects requiring real thought and initiative on the student's part; instruments and materials for such diversified activities as soil testing, spectroscopy, and harnessing solar energy. These and many more stimulating new instructives make this unique science materials catalog essential to forward-looking teachers on all grade levels.

Edmund's well known values in science equipment—telescopes, microscopes, optical materials, and many other school requirements—are also included in this Catalog. For standard values and exciting new offerings write for

.. Edmund's 1961 Educational Catalog—"SK".

ORDER BY STOCK NUMBER · SEND CHECK OR MONEY ORDER · SATISFACTION GUARANTEED!

EDMUND SCIENTIFIC CO., BARRINGTON, NEW JERSEY

CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS—OFFICERS FOR 1961

President—Cecil B. Read, University of Wichita, Wichita, Kansas
Vice-President—Alice M. Hach, Ann Arbor Public Schools, Ann Arbor, Michigan
Secretary-Historian—Joe Kennedy, Indiana State Teachers College, Terre Haute, Indiana
Treasurer-Business Manager—Luther Shetler, P.O. Box 108, Bluffton, Ohio

EXECUTIVE COMMITTEE FOR 1961

Cecil B. Read, President
Alice M. Hach, Vice-President
James H. Otto, President for 1960, George Washington High School, Indianapolis, Ind.

BOARD OF DIRECTORS FOR 1961

Ex-Officio

Cecil B. Read, President
Alice M. Hach, Vice-President
James H. Otto, President for 1960

Terms Expire in 1961

Lawrence A. Conrey, University High School, Ann Arbor, Michigan
David Laird, Washington Township High School, Centerville, Ohio
R. Warren Woline, Oak Park-River Forest School, Oak Park, Illinois
Aubrey G. Wood, Memorial High School, Beloit, Wisconsin

Terms Expire in 1962

William A. Hill, Naperville High School, Naperville, Illinois
Donovan Johnson, University of Minnesota, Minneapolis, Minnesota
Sister Mary Ambrosia, Holy Redeemer High School, Detroit, Michigan
Glen D. Vannatta, Broad Ripple High School, Indianapolis, Indiana

Terms Expire in 1963

Carl W. Clader, New Trier Township High School, Winnetka, Illinois
M. Wiles Keller, Purdue University, Lafayette, Indiana
T. Reginald Porter, State University of Iowa, Iowa City, Iowa
Joseph J. Urbancek, Chicago Teachers College, Chicago, Illinois

JOURNAL OFFICERS

George G. Mallinson, Editor, 535 Kendall, Kalamazoo, Michigan
Jacqueline Mallinson, Assistant Editor, Kalamazoo, Michigan

SECTION OFFICERS FOR 1961

(Order: Chairman, Vice-Chairman, Secretary)

Biology and Conservation

Robert C. Wallace, Reavis High School, Oak Lawn, Illinois
Louis E. Shrode, Oak Park-River Forest High School, Oak Park, Illinois
Byron G. Bernard, LaPorte High School, LaPorte, Indiana

Chemistry

Carl J. Engels, Western Michigan University High School, Kalamazoo, Michigan
Virgil H. Heniser, Howe High School, Indianapolis, Indiana
Eugene Herbener, Trenton High School, Trenton, Michigan

Elementary Mathematics

Joseph N. Payne, University of Michigan, Ann Arbor, Michigan
Joseph J. Stipanowich, Western Illinois University, Macomb, Illinois
David W. Wells, Oakland County Schools, Pontiac, Michigan

Elementary Science

Barbara Wehr, Laboratory School, University of Chicago, Chicago, Illinois
Virginia Tileston, School 68, Indianapolis, Indiana
Joseph Lucci, Mettatal Junior High School, Detroit, Michigan

General Science

David Schulert, Lansing Public Schools, Lansing, Michigan
Sister Mary Imelda, St. Cyril High School, Detroit, Michigan
Thomas Given, Brownell Junior High School, Grosse Pointe, Michigan

Mathematics

Thomas Schneider, Cody High School, Detroit Michigan
Ralph Smith, Oak Park-River Forest High School, Oak Park, Illinois
Edith Benjamin, Arlington Heights High School, Arlington Heights, Illinois

Physics

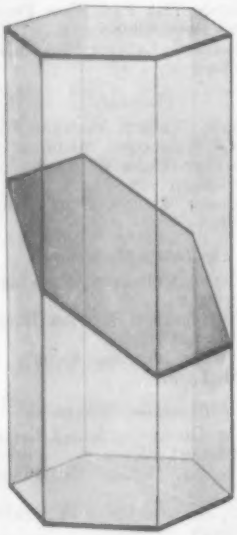
Richard F. Olufs, Grayslake High School, Grayslake, Illinois
Jerry M. Colglazier, Franklin Central High School, Acton, Indiana
Bert S. Buscher, DeKalb High School, DeKalb, Illinois

Welch

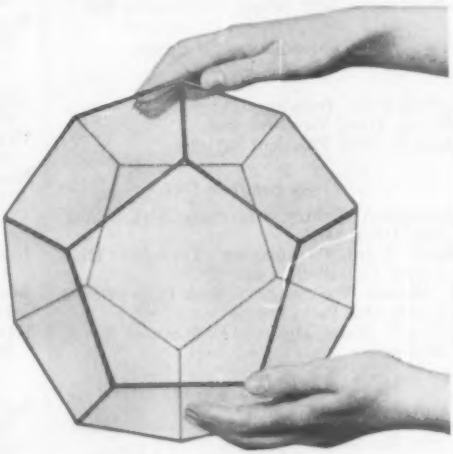
24 Transparent Mathematics Models Especially Suitable for Demonstration

NEW LARGE SIZE

Average One Foot High—Some as large as 15 inches



No. 7577 Hexagonal Prism
Each $9.50



No. 7592 Dodecahedron
Each $12.50

Permit the Class to see them in detail.

Carefully made of Crystal Clear, heavy, transparent plastic with sections and some parts of brightly colored plastic.

Valuable teaching aids in plane and solid geometry, algebra, and other mathematics classes.

Degree of accuracy provides that measurements may be taken from them for numerical problems.

Write for circular describing all 24 models.

The Welch Scientific Company

Established 1880

1515 Sedgwick St. Dept. S Chicago 10, Ill.

Manufacturers of Scientific Instruments and Laboratory Apparatus

SCHOOL SCIENCE
AND
MATHEMATICS

VOL. LXI APRIL, 1961 WHOLE NO. 537

What Does the Future Hold for Junior High Science?

An Open Letter to Junior High Science Teachers

Norman D. Anderson

Science Teacher, Township of Pleasant Valley High School, Bettendorf, Iowa

and

Walter R. Brown

Asst. Prof. of Education, The University School, on leave 1960-61 Florida State University, Tallahassee, Florida

During the 1950's we have seen many dramatic innovations in the teaching of science. Any list of these would certainly include the several attempts to study science curriculum on a national scale (PSSC, AIBS, CBA). We have seen an increase in activity by the Federal Government in the form of such programs as NDEA, NSF, and others. We have witnessed the introduction of new techniques in teaching such as educational television, new film series, and the use of teaching machines. We have moved much closer to the dream of a science program for every student from kindergarten through high school. And we have participated in an unprecedented growth in professional organizations. Whether or not we presonally feel that all of these have been advances, we cannot but admit that the fifties have seen great changes in science education.

What do the sixties hold for science eduction? More specifically, what do the sixties hold for junior high science? Of course, no one can forecast with any degree of accuracy what changes will take place, but we feel that we can predict even greater changes than those which occurred during the last decade.

The junior high school in general, and junior high school science in particular, have not received their share of study in recent years. There were more than 25 major books published on the junior high school prior to 1930, and only two from 1931 through 1947.[1] This trend has continued to the present time. The lack of research and literature on junior high science is in the same disappointing proportion.

Research evidence indicates continuance of internal school reorganization leading to the establishment of more junior high schools.[2] As these schools increase in number and in enrollment, we can expect an increase in departmentalization. Regardless of the administrative plans involved, there are approximately eight million students enrolled in Grades 7-8-9 during the current year. The percentage of these enrolled in science is presently being determined by the U. S. Office of Education and these statistics should emphasize in still another way the importance and magnitude of the junior high school science problem.

It is a widely accepted belief that the junior high program has an important influence on a student's interest and on his future educational and vocational choices. Much of our effort, however, has been aimed at the improvement of the senior high school and college programs. The 59th Yearbook authors realized this problem and called for one possible solution:

> The reported "damping off" of science interests of pupils after the sixth grade or seventh grade is accounted for in part by the fact that science beyond these levels is too frequently taught by teachers poorly prepared in science. Because of the central nature of these grades, teachers with the very best preparation should be teaching seventh- and eighth-grade science.[3]

Based on these three points—the lack of attention given junior high science during the past decade, the large number and percentage of junior high students enrolled in science, and the marked psychological effects of science experiences at this level—we are convinced that the sixties *must* be a decade of productivity in the teaching of science in the junior high school. In an attempt to focus attention on this much needed action, we ask you to react to the following four questions which we have aimed specifically at the junior high school science teacher:

1. *What do you believe are the characteristics of a good junior high science program?* We feel that a good program is one that results in students emerging with an increased interest in science. Regardless

[1] Lounsbury, John H., "What Has Happened to the Junior High School?" *Educational Leadership*, 13:369 (March), 1956.

[2] Koos, Leonard V., *Junior High School Trends* (New York: Harper and Brothers, 1955), p. 4.

[3] Henry, Nelson B., Editor, *Rethinking Science Education: The Fifty-Ninth Yearbook of the National Society for the Study of Education, Part I* (Chicago, Illinois: University of Chicago Press, 1960), p. 159.

of all other outcomes, our primary concern is with the development of an active interest in, and curiosity about, science. We would also, of course, hope that the program would result in an increase in such things as the student's ability to solve problems, functional knowledge of his environment, and appreciation for the role of science in his life.

2. *What are your responsibilities in the formulation of junior high science programs?* Junior high science teachers across the country have a responsibility to take the lead in the establishment of improved or new junior high science programs. True, other science teachers, educators, and scientists will be able to provide valuable assistance. But you, and you alone, by virtue of your training and experience, have the necessary qualifications for this leadership.

3. *What do you as a science teacher feel are your responsibilities to all junior high pupils?* We feel that we have a very real responsibility to all of the students in our school, regardless of their abilities, backgrounds, and future plans. For many, junior high represents the major opportunity for meaningful experiences in science. Surely, this fact is important enough to be given consideration in the design of a program.

4. *What qualities do you think are needed to be a good junior high science teacher?* We hope that by now it is apparent to the reader that we consider you, the junior high science teacher, a broad-field specialist in a very difficult, yet exciting field. Our hope for the solution of these important problems lies largely in the training of *special* teachers for junior high science—teachers with broad training in both subject matter and methods. Proper training coupled with interest in making junior high science teaching a career will surely provide part of the answer to the junior high science problem.

These four generalized questions are meant to be samples of those problems facing us today. We hope that they will stimulate the formulation of many others, and eventually the answers to some.

Will one of the outcomes of science education in the 1960's be a new and improved junior high science? If it is, it will be attained only through your efforts in thinking actively about the problems, participating in special meetings, developing and promoting studies and research problems, and especially through communication among ourselves. As one junior high science teacher to another, can we count on *you?*

OHIO ACADEMY OF SCIENCE

The annual meeting of The Ohio Academy of Science, will be held at the University of Cincinnati, April 20–22.

Some Psychological Principles Underlying Mathematics Instruction*

H. Van Engen

University of Wisconsin, Madison, Wisconsin

A study of the history of the mathematics curriculum in the U. S. will reveal that the mathematics of the schools has been influenced by 1) shifts in the philosophic positions of educators and lay groups, 2) changes in sociological conditions, 3) the demands of industry and a rapidly expanding technology, and 4) the basic principles of a psychology of learning commonly held by those who create climates of opinion. At present we are in a period in which the technological changes that are occurring in our Land are forcing the schools to take a long hard look at mathematics and science courses. The mathematics of yesterday is not the mathematics for today. For some, it is hard to realize that the spirit and content of school mathematics must change if the schools are to serve our twentieth century America.

As the work progresses in revising the curriculum, it is apparent that the psychological positions of thirty to fifty years ago are just as inadequate as the mathematics of this period. The old faculty psychology that held the center of the stage from Plato's time to the beginning of the twentieth century has been thoroughly discredited. The Thorndikian psychology of the twenties and the thirties still holds some of our schools in its rigid stimulus-response grasp. If this were not so, how else could one explain the atomization of the arithmetic and algebra as they occur, all too frequently, in the schools? For example, in the algebra classes of years ago the solution of equations was taught by types with little thought for a basic pattern of thought. In arithmetic, long division was taught, and, all too frequently, still is taught, in some thirty to forty lessons, scattered throughout the fourth, fifth, and sixth grades, without once developing a central idea and a basic mathematical principle. In the light of what is known today, these positions are untenable. The stimulus response principles of thirty years ago must be used with great care, in constructing a learnable sequence of ideas for the schools.

What then are some basic psychologically oriented principles that can serve to develop readily learnable sequences of mathematical ideas for the schools? This paper will discuss and illustrate the uses of only a few such ideas. A more complete discussion can be found in the literature pertaining to the teaching of mathematics.[1]

* A paper presented at the Annual Convention of the CASMT, Detroit, Michigan, November 24-26, 1950

[1] *The Learning of Mathematics: Its Theory and Practice*, Twenty-first Yearbook of the National Council of Teachers of Mathematics. Washington, D. C.: The National Council of Teachers of Mathematics, 1953.

The first of the fundamental principles that must be kept in mind by all who profess to work with human beings, and in particular school children, is the tendency of the human mind to think in terms of physical things and events. The mathematician recognizes this fact when he illustrates his lecture in advanced mathematics by means of a picture on the board. A good illustration of this technique is the excellent film by E. J. McShane on Limits. The visual aids used in this film were not necessary for the mathematics but they were essential for illustrating the meaning or pattern of symbols. The things of this world, if properly used, are the source of many ideas of interest to mathematicians.

Psychologists recognize that children and adults learn by abstracting from the physical world. We need give only two quotations from the many that can be found in the literature. "So that everything we have said in this work is to show that the thought of the child is less conscious than ours has *ipso facto* led us to the conclusion that childish thought is devoid of logical necessity and genuine implication; it is nearer to action than ours, and consists simply of mentally pictured manual operations, which, like the vagaries of movement, follow each other without any necessary succession.

These movements and operation are a preparation for conscious reasoning insofar as they reproduce and prepare anew the manual operations of which thought is a continuation."[2]

Werner says,

"The child's concepts always have a concrete content. Image and concept are an indivisible unity. The conceiving and the describing of a thing are not distinctly separated activities. As is true of primitive man, the child's need of adjustment to adult language creates conceptual forms which arise out of concrete perception, which are indeed both perception and conception, which appear to be metaphors and yet really are not. . . . To conceive and define things in terms of concrete activity is in complete accordance with the world-of-action characteristic of the child."[3]

Almost any observing teacher of young children, or an observing parent, will recall experiences which verify the generalizations given in these quotations. Teachers know that to a child a ball is "Something you throw," and a knife is "Something you cut with." The reliance on physical things to produce a feeling of oneness in the world of symbolism is illustrated by the ninth grader who was somewhat doubtful about 8 being the correct answer for $6-(-2)$. He said, "Show me that it works in dollars and cents and I'll believe it."

---

[2] Piaget, Jean, *Judgment and Reasoning in the Child*. New York: Harcourt, Brace and Co., 1928, p. 145.

[3] Werner, Heinz, *Comparative Psychology of Mental Development*. New York: Harper and Brothers, 1940, pp. 271–72.

In other words, this ninth grader felt better about the difference being greater than either the minuend or subtrahend if he could think of concrete things. He was abstracting from the physical world, and he was trying to verify that the abstraction was a valid one.

Furthermore, what teacher would dream of teaching geometry without drawing pictures of lines, triangles, and points on the chalkboard? All this in spite of the fact that the pictures of lines and points on the board are not the lines and points in the mathematical system. Here the appeal to physical things enables the student to take a first step in his study of mathematical systems.

Let us make the generalization that is inherent in the above remarks. It is a fundamental problem of curriculum construction to so plan the child's experiences with the things of this world that he can arrive at the study of mathematics—a mathematics without reference to the things of this world. In other words, it is a fundamental problem of curriculum construction to plan the pupils experiences so as to enable him to divorce his thinking from physical things and to transfer his thought patterns to mathematical entities. The child must be lead from physics to mathematics. This means that the teacher must select a model of the mathematical system to be taught and lead the child to abstract from the model to the system.

This position has many important implications for instruction. Just a few of these implications will be discussed briefly.

1. A cardinal number is a number associated with a set of objects. As such it has nothing to do with the color of the objects or the length of a stick formed by gluing together several blocks, or the shape the group of objects may have taken when viewed as a set. Hence, those methods of instruction that use color recognition, or length, or volume as a primary ingredient in the first experiences for developing the concept of number are false leads. They are "pools of quick sand" in the path of easy concept development. Experiences based on physical properties, such as recognizing three because the blocks are red, cannot serve as the model for the mathematical concept of cardinal number.

Neither should the first experiences with number be based upon hazy mathematical ideas such as the property of a set of sets of objects. A set of sets may have no property or it may have many properties. Hence, to teach a child that a number expresses a property of a set of sets is not good mathematics, and it is much worse than "not good" as a psychological foundation for number ideas. In this case, the model obstructs teaching because, in addition to its not being mathematically defensible, the property cannot be made evident to the five year old.

It is a sad comment on the depth of thinking exhibited by some

research mathematicians interested in educational problems who give smiling approval to proposals for elementary instruction that do not "fit" good mathematics. "Colored" number is one illustration. Teaching that two is the property of the set of all sets of couples is still another.

On the other hand, recent literature on teaching mathematics contains proposals that are mathematically sound but for which adequate models are not available from which the child can sense the mathematical structure. As examples of proposals showing a woeful lack of psychological insight one can cite those who advocate the use in the third grade of the cross-product of two sets as the definition for multiplication and the use of the elementary ideas of analytical geometry to teach the multiplication facts in the elementary school.

2. The first steps children are asked to take to form a concept of a mathematical operation is not easily discernible in many elementary programs. For example, those experiences needed to serve as a model of the mathematical idea of an operation are too frequently absent or not clearly pointed out in instruction. The mathematical idea, in this instance, is based on the union of two disjoint sets. The child must learn that the number associated with the union of a set of 5 objects and a set of 8 objects is symbolized by 5+8. He must learn that this same symbol is associated with the union of these two sets regardless of the kinds of objects in the sets. Thus, the number associated with the union of a set of 5 cats and 8 chickens is also symbolized by 5+8. Another name for 5+8 is 13. It is the standard name for the set which results from the union under consideration. Such experiences enable the child to take the first step in recognizing what the operation of addition is. As he progresses through the years of schooling, he learns that this operation has several properties and, in particular, he learns that addition is a function. In this instance, the model fits the methematical idea. The path from physics to mathematics is clear and straight.

Consider the implications this position holds for curriculum construction. Not too long ago, teachers always taught the basic addition combinations before they undertook to teach the problem solving. Too frequently, this is still the case. Consider this problem. John has four apples. His mother gave him two more apples. How many apples does John have now? If the point of view advocated in this paper is taken, teachers must use this problem as an instance in which the child must recognize the union of two sets. The child learns that the number associated with this union is symbolized by 4+2 and that all other unions of a set of 4 with a set of 2 are also symbolized by 4+2. Furthermore, he learns that the standard name of 4+2 is 6, and that this combination occurs so frequently that he must mem-

orize it. Briefly, we are saying that certain well selected problem situations form the basis for developing the concept of addition. After having taken the first steps toward understanding addition the child learns to memorize the number combinations. This is just the reverse of the sequence of events as arithmetic was taught some years ago.

Consider a few ideas from the more advanced mathematics in the schools. Let us go to first year algebra for our illustration.

3. Efforts to revise the mathematics curriculum are well under way at present. It is known that some mathematicians reject the placeholder idea as a valid basis on which to develop the idea of a variable. This is a mistake. There is a certain "earthiness"—a closeness to action—about the placeholder idea. The pupil thinks of "taking" a number from the universe and replacing the variable by that number. He then reacts to see if he has a true statement. These are first experiences with letters to hold places for numerals. These experiences are close to action—it is something a child can do with letters and numerals to reach a decision. Psychologically, the placeholder idea forms a sound basis for the first steps to take in grasping the use of letters in mathematics. To substitute the definition which says that a variable is the name of some unspecified member of a given set can only make the first steps harder to comprehend. The placeholder idea can be attained in the late elementary grades. This cannot be done with the "unspecified name for a member of a given set" definition of a variable. This lesson has not been learned by many who are at present writing for the elementary and junior high school.

Failure to provide an "action type" experience is all too common in materials that are now appearing for our schools. Witness the attempts to formulate a generalization about number in the junior high school before having said anything about how letters are used in mathematics.

As a good example of such mystical writing, one need only cite recent fourth grade materials in which the letters A, B, and C are used as the names for numbers and a generalized form for subtraction written down without developing a psychologically sound background for such language. The generalization, in this instance, was attained within the space of one line of printed words.

It is essential that teachers become aware of at least one of the "Dangers of Our Times." It is very difficult to make some mathematicians understand that what is important to a learner as a learner may not be important to a mathematician as a mathematician. This statement is true also about mathematicians who are sincerely interested in improving school mathematics. Mathematical structures, mathematical language, mathematical idioms, and mathematical

patterns of thought are not necessarily structured so as to be easily learned by adolescents. They are structured so as to be useful to the mathematician as a mathematician. For example, the statement that, for all a, b, and c, $a(b+c) = ab+ac$ is simple and straightforward to a mathematician but to a first year algebra student it can easily become a series of hieroglyphics to be memorized if not properly taught. Furthermore, such statements will remain a series of meaningless hieroglyphics for most algebra students unless the proper foundation is laid for just such mathematical idioms. For a mathematician with strong intuitions about mathematical entities (and these intuitions must be strong if he is a good mathematician) it is difficult to comprehend what must be done to make this a meaningful statement to a fourteen-year-old boy or girl. It is difficult to make some mathematicians comprehend that the distributive law can cause trouble at the very outset of the study of first-year algebra.

Those teachers interested in the learning problem in secondary mathematics must make it known that what is important to a mathematician must be important to the budding young mathematician in our schools, but the converse of this theorem is not true. What is important to the learning of mathematics frequently is of little importance to the mathematician. And herein resides one of the "Dangers of Our Times."

We come now to the second psychological principle to be discussed in this paper.

Continuity is a basic principle of curriculum construction. By continuity is meant the smooth flow of ideas from paragraph to paragraph, chapter to chapter, and year to year. The principle of continuity implies that the ideas in the curriculum are structured, that is, that the basic ideas of the subject are so related that they seem to be placed "on top of the other." Furthermore, this system of ideas is complete. There are no holes and no big gaps in the structure.

It is of more than passing interest that curriculum specialists, psychologists, and mathematicians have made considerable use of the term structure. Each group uses the term in a somewhat different sense, but there is a vast amount of similarity in the use of the term by the psychologist, the mathematician, and the curriculum specialist. There are also differences. The mathematician can exhibit an instance of structure somewhat more readily than the curriculum specialist. The psychologist has more difficulty than almost anyone else if requested to give a good illustration of his concept of structure. Yet, for the psychologist structure is there, and its characteristics are much like the structure of the mathematician. In each case, it is a fitting together of parts to make a well defined whole.

This interest in structure in the various fields of education is no

mere coincidence. Its use indicates how basic structure is to the educational process. Bruner, a psychologist, in his recent book, *The Process of Education*, takes structure as one of his central themes. He claims, "(1) Understanding fundamentals makes a subject comprehensible, (2) memory requires a structured pattern, (3) understanding general or fundamental principles is the main road to the transfer of training, and (4) constant re-examination of material, as it is taught in the elementary and secondary school for fundamental character, narrows the gap between advanced knowledge and elementary knowledge."

Major efforts to reform the curriculum have been centered around the central idea of a mathematical structure. Most certainly, as was pointed out in the first section of this paper, mathematical structure must play a central role in curriculum reform. Schools cannot teach contemporary mathematics unless the curriculum reflects the things that contemporary mathematicians are interested in. However, once having decided upon the mathematical structure that seems the most appropriate for the schools, there remains the very difficult problem of structuring the sequence of ideas from grade K through 12 so as to make the mathematical structure easily understood. The mathematician with his strong intuitions about mathematics and the secondary school teacher with weak intuitions about the certain psychological problems involved in learning mathematics do not always form a good team. As a result, some recent materials for use in the schools are more difficult than they need be and in some instances the goals are unattainable. Consider just a few examples.

1. It is standard practice in mathematics to define a rational number as the quotient of two integers. This definition requires a considerable degree of mathematical sophistication if it is to be understood. This definition requires more mathematical sophistication than a junior high school methematics pupil possesses if he is to reach psychological closure. Before this definition can be understood, the junior high school pupil must know that the algebra of quotients is the same as the algebra of rational numbers. In fact, the quotients of integers and the rationals are isomorphic. If the junior high school pupil is to understand this, the proper foundations must be laid. This is very seldom done. In the recent efforts to improve the mathematics curriculum, too little attention has been paid to just this type of problem. Mathematics cannot be easily learned unless its ideas are structured and unless the sequence of learning experiences are structured.

2. As has been said before, the schools must give particular attention to the structure of mathematics. In fact, some contend that the

overriding objective of the schools is to give the high school student some concept of a mathematical structure before he graduates. However, to achieve this objective the high school student must be taught the techniques of a mathematical argument. Within the body of the proof of any theorem there are three or four standard techniques of logic that every high school student should be well acquainted with. These techniques have a structure, just as much as mathematics has a structure. These structures are similar, yet different. But this is not the main point. I have quoted from Bruner, to the effect that learning requires a structured pattern. Hence, if a student is to learn how to prove a theorem he should understand the strategies used most frequently in the proof of a theorem. This fact has been thoroughly neglected by most groups; the most notable exception being the University of Illinois group (USICSM).

It is well known that in a mathematical system the first few theorems are usually proved by means of an indirect proof. In the SMSG materials, the first theorems in both first year algebra and geometry require indirect proofs or are uniqueness proofs. It is hard to convince students that an indirect proof is a proof at all. There is something mysterious about it. For this reason, it is questionable whether the student should encounter indirect proofs as his first experience with proof. It is also questionable whether students should be "just pushed into proofs" without an adequate study of such things as rules of inference, how to deny a theorem, and contrapositives. If, as some psychologists claim, structured learning is the most fruitful learning, then present practices with respect to strategies of proof cannot be condoned.

3. As our third and last illustration, we invite you to consider the larger problem of structuring a curriculum from the kindergarten to the college. Up to the present day, this problem has not been attacked by any national group. True, the curriculum has been studied chapter by chapter and grade by grade by various subsets of the mathematical world, but a detailed study which tries to visualize a continuous sequence of ideas for the schools has not been undertaken.[4] This situation should not continue to exist. Some of the larger and more important learning problems are obscured by a local study, that is, a grade by grade study by different committees, such as is now being attempted. Examples of such problems are: (1) What do we do about the real number system in the first twelve years of school? (2) How do we develop the idea of a mathematiccal structure in the schools? Should it be first taught in the tenth grade? The sixth

[4] The Commission on Mathematics of the College Entrance Examination Board concerned itself with the gross structure of the curriculum.

grade? (3) Should we have a one-track program for all or a multiple track program for segments of the school population? (4) What mathematics can *and should* be taught at the various age levels? These problems, and a multitude of other problems, cannot be solved by committees whose sole responsibility is to develop a course for a particular grade. The schools of America need a comprehensive study made by a committee composed of the best of the various talents that are available in America. The money is available, but it would seem that our imagination has not been sufficiently developed. Or is it that the mathematical community does not really understand the larger problems which confront it when constructing a curriculum for the schools of America? If not, it is up to the school people to impress upon those whose influence is dominant that the problems of mathematics are not solved piecemeal. We need a structured attack on school problems just as badly as we need a structured mathematics in the schools. Let us hope that the time will not be long before we see a comprehensive attack on the broader problems of mathematics instruction.

ONE OUT OF THREE CANCER PATIENTS ARE BEING SAVED

One cancer patient out of three is now being saved. The gain in lives saved amounts to 42,000 lives a year for the past ten years.

The 1961 Cancer Facts and Figures of the American Cancer Society says there are more than a million Americans who are alive and without evidence of cancer at least five years after diagnosis and treatment.

There are 600,000 more who have been treated and who will probably be counted cured when five years have elapsed after the end of their treatment. However, curing one out of two who get cancer today is the immediate goal.

Death rates from lung cancer continue to show an increase, although those for uterine cancer have declined, and death rates from most forms of cancer have been stabilized.

If present trends continue, 1,000,000 children now in school will die of lung cancer before they reach 70. In 1961, an estimated 37,500 Americans will succumb to this kind of cancer, 32,400 of them men; 5,100, women.

Although there are more than 180,000 women alive who have been saved from uterine cancer, some 14,000 women die from it each year. The U. S. death rate from this form of the disease has declined 40% in the last 25 years among white women and 25% among Negro women. The Society credits the decine to earlier diagnosis and treatment.

Most of the 14,000 deaths from uterine cancer each year are unnecessary because new detection and treatment methods make this type of cancer nearly 100% curable, the booklet says.

The ratio of men to women dying of cancer continues to be greater for men, which has been true since 1949. The ratio in 1961 will be about 54 men to 6 women.

The AAAS Feasibility Study on Science in the Elementary and Junior High Schools

John R. Mayor

Director of Education, American Association for the Advancement of Science, Washington, D. C.

During the past few years, one-year senior high school courses for biology, chemistry, and physics have been developed by teams of scientists and teachers, and have been widely tried out in the schools. These courses give great promise for improving science offerings in the schools for students interested in the study of science for general education and also for students who will become the scientists of tomorrow. The new science courses reflect the modern point of view in science and they represent a new departure in education in which teachers in a given field at all levels work together in an attempt to produce the best possible materials for a year's course in the senior high school. Similarly, experimental courses have been prepared for use in mathematics from grades 4 through 12, as well as at the college level. There has been no comparable work on a national scale in elementary and junior high school science.

It is easily recognized that the problems of developing courses in science for the elementary and junior high school are much greater than those at the secondary-school level and more difficult in science than in mathematics, which has a more traditional place in the curriculum. There is no general agreement on which sciences should be included in such sequences and when they should be taught. The common pattern is for general science in grades K through 9. It is, of course, more difficult to obtain outstanding scientists to work on courses general in nature, rather than to work on courses in their own special field. In the elementary school, special problems arise as a result of the current general acceptance of the self-contained classroom.

Recognizing a need for the improvement of science offerings in the grades preceding the tenth, the AAAS has embarked upon a feasibility study of what needs to be done and how it can best be carried out. This study is being conducted with the support of the National Science Foundation. One of the steps in the study is a series of regional conferences, the first of which was held in St. Louis in January, the second in Berkeley, California in February, and the third in Washington in March. Working papers were prepared for use of participants in these conferences, setting forth background of the current status of courses of study and textbooks in elementary and junior high school science. The Steering Committee in charge of the

feasibility study is pleased to have this opportunity to publish these working papers* in SCHOOL SCIENCE AND MATHEMATICS, with the hope that they might be of value to a much wider group than those who have been attending the regional conferences. In the spring a final report of the feasibility study will be made.

Members of the Steering Committee for the Study are: Paul E. Blackwood, Specialist for Science, Elementary School Section, U. S. Office of Education; Margaret W. Efraemson, Elementary School Principal, Rudolph S. Walton Public School, Philadlephia; Paul M. Gross, Department of Chemistry, Duke University; Thomas S. Hall, Dean, College of Liberal Arts, Washington University; Philip G. Johnson, Chairman, Section on Science Education, Cornell University; John R. Mayor, Director of Education, AAAS; Thornton Page, Department of Astronomy, Wesleyan University; Dael Wolfle, Executive Officer, AAAS.

Dean Thomas S. Hall served as chairman of the St. Louis Conference; Professor Owen Chamberlain, Department of Physics, University of California, chairman of the Berkeley Conference; and Professor John Toll, Department of Physics, University of Maryland, as chairman of the Washington Conference.

The Current Status of Science Education in the Elementary Schools

Jacqueline V. Mallinson

Western Michigan University, Kalamazoo, Michigan

INTRODUCTION

It is commonly stated that science is the "step-child" of the elementary school curriculum. If the pattern for the teaching of the other basic academic areas is any criterion, the description is eiminently justified. No person can dispute the fact that science instruction in the elementary school is still immature and disorganized as compared with the instruction in the "Three R's." Without doubt there are many factors that have contributed to the situation. How-

---

* The five working papers prepared for use at these conferences are concerned with a survey of elementary science education; a survey of junior high school education; an analysis of elementary science textbooks; a review of current curriculum activities in elementary and junior high school science; and science education in Western Europe.

The first two papers appear in this issue; the next two will appear in the May issue; and the final one in the June issue. SCHOOL SCIENCE AND MATHEMATICS is pleased to be able to present these important papers for its readers.

ever, two of the more significant are the "newness" of science in the elementary school, and the "downward" development of the science program.

It is true that some variety of science experiences has been offered in the elementary schools for several centuries. However, it is equally true that most of these experiences have been oriented around the nature-study approach. Further, much of the instruction in science has frequently been treated as an adjunct to other areas of the curriculum. The relationship of elementary science to nature study is indicated in a UNESCO report (26) concerned with science teaching in the primary school in the following statement: "Elementary science . . . had its origin in the United States of America more than a quarter of a century ago and is gradually replacing nature study in the primary schools there." Several research studies (8, 21) have also indicated the nature of these early science courses. Suffice to say, all of them point to a "spotty" organization, and a program emphasizing topics from the biological sciences.

The first influential statement of the role of science in the elementary school appeared in the Thirty-First Yearbook of the National Society for the Study of Education, entitled *A Program for Teaching Science* (1). Here, for the first time, a committee of experts in science education stated that a continuous, sequential program of instruction should begin in the kindergarten and extend through grade 12. This was indeed a milestone in elementary science education.

An organized program of science had, of course, existed in the secondary schools long before the appearance of elementary science. It is outside the scope of this paper to trace the history of science instruction at this level. Nevertheless, it is evident that science courses were first offered at the top levels of high school, and shortly after the turn of the century, gradually moved downward into the junior high school. Finally, with the publication of the Thirty-First Yearbook, the idea for the continuous program was given credence at the elementary level. Obviously the science program reflects this downward development. In most cases, the program is strongest at the upper levels and weakest at the lower.

The Elementary-Science Program

Obviously well-developed curricula in elementary science did not emerge immediately with the publication of the Thirty-First Yearbook. As with nearly all developments in education, there was an "educational lag" between the desirable situation and actual practice. In fact, a marked disparity still exists at even the present time. The reasons for the continued disparity are many and varied. Never-

theless, there is evidence that within recent years, elementary-science instruction has matured more than many secondary and college-level personnel realize. Some of the elements related to the maturation will be described in the sections that follow.

The Objectives of Elementary Science:

Much has been written concerning the objectives of elementary-science instruction. The literature is replete with well-phrased and philosophically-sound objectives that apply at this level. One of the most widely accepted lists is found in the Forty-Sixth Yearbook of the NSSE (25). The list includes the following major objectives:

A. Functional information of facts about such matters as:
   (1) Our universe—earth, sun, moon, stars, weather.
   (2) Living things—plants and animals.
   (3) The human body—structure, function, and care.
B. Functional concepts such as:
   (1) Space is vast.
   (2) The earth is very old.
   (3) All life has evolved from simpler forms.
   (4) All matter is probably electrical in structure.
C. Functional understanding of principles, such as:
   (1) All living things reproduce their kind.
   (2) Energy can be changed from one form into another.
D. Instrumental skills, such as ability to:
   (1) Read science content with understanding and satisfaction.
   (2) Perform simple manipulatory activities with science equipment.
E. Problem-solving skills, such as ability to:
   (1) Sense a problem.
   (2) Make the best tentative explanation or hypothesis.
   (3) Test the hypothesis by experimental or other means.
F. Attitudes, such as:
   (1) Open-mindedness, willingness to consider new facts.
   (2) Intellectual honesty—scientific integrity.
G. Appreciations, such as:
   (1) Appreciation of the contributions of scientists.
   (2) Appreciation of the basic cause and effect relationships.
H. Interests, such as:
   (1) Interest in some phase of science as a recreational activity or hobby.
   (2) Interest in science as a field for a vocation.

Many other lists similar to this one appear in various publications. It would be difficult to challenge the merits of the elements in the above list, or for that matter, those that appear in other lists. Unfortunately, however, these lists have had little influence on the elementary-science program. If these objectives are examined carefully, it is clear that they are couched in academic pedagese and are too nebulous and vague to give the typical elementary teacher the needed for teaching science. In effect, the Yearbooks and other sources had provided worthy outcomes, but had failed to suggest specific means for attaining them. As a result, the objectives were platitudes for discussion, rather than specific guides for operating

elementary-science programs. Consequently, it is reasonable to state that one cause for the present turmoil in elementary science is the lack of a clear-cut, easily-understood list of objectives that can be implemented by the classroom teacher. As a result, most elementary teachers cannot state clearly the reasons why they teach science.

In an effort to attack the problem, a number of science educators have sought to clarify and simplify the objectives of elementary-science instruction. They have recognized two dimensions of science instruction, namely (1) the knowledge, or factual, dimension, and (2) the performance, or "doing," dimension. Both dimensions are accorded equal emphasis.

The knowledge, or factual, dimension has been fairly well established. Some of the areas of knowledge are discussed in later sections. The performance dimension, however, is much less well established. Nevertheless, there have been attempts to define what an elementary student should be able to "do better" as a result of science instruction. One such list follows:

Science instruction should enable a student to:

1. Observe the objectives that exist, and the phenomena that take place, in his environment and to report accurately what he observes. In other words, the student should be taught to describe.

   (The word "observe" refers not only to the use of the eyes to see, but also to the use of the ears, nose, tongue and fingers, in order to hear, smell, taste, and feel. Further, it implies the opportunity to report or describe the experience using all media of communication such as speaking, writing and drawing. The student should also learn the limitations of the human senses and the values of instruments and units of measurement for supplementing his senses.)

2. Compare objects and phenomena with respect to their (a) likenesses and (b) differences. These two skills are different from one another.

   (Comparison with respect to difference is a skill learned more easily than is comparing objects and phenomena to ascertain their likenesses. These two "doings" involve such questions as "In what ways are they alike"? "In what ways are they different?" Activities here may involve collecting, tabulating, mounting, and examining. However, the emphasis is on the comparison of objects, specimens and phenomena, *not* on merely memorizing parts and structures.

   Obviously, younger children are more capable of recognizing gross differences; but as they mature, they should be able to recognize likenesses, also. Naturally, these skills are dependent on the abilities to observe and describe.)

3. Rank information in terms of its importance.

   (In every science experience in which a student collects data, it is obvious that some data are more important for describing or comparing objects or phenomena than are other data. The student should, therefore, learn to catalogue information in terms of its importance or relevance to a situation. They should learn to distinguish the "important" from the "not-so-important" items of information. "Sharing period" and groups discussions the "important" from the "not-so-important" items of information. "Sharing period" and group discussions offer fine oppor-

tunities in which to help youngsters develop the skill of pointing out the important facts, and eliminating the irrelevant ones.)

4. Determine whether there is enough information available to warrant making a conclusive or even tentative answer; or, deciding how much of an answer can be made from the information available.

   (Obviously, the study of a science unit should be preceded with the listing of questions that the students would like to have answered. After the data are collected and sorted, the students should decide whether the information available is sufficient to answer the questions. This may be done individually or in group discussion. However, practice should be given each student so that he will learn to decide on "enough" or "not enough" information. Many children, as well as many adults, have the habit of "jumping to conclusions." Hence, this skill is a most important one).

5. Determine what *kind* of information is still needed in order to formulate an answer to a question, or locate data for a problem.

   (The doing described here is related to the one in 4 above. If the student finds that certain questions cannot be answered because of insufficient data, he should be expected to analyze what he has collected to determine the *kind* of information still needed. He should, therefore, analyze the aspects of the questions that are still unanswered and the areas of information that need to be explored.)

6. Decide on the most efficient way to obtain the needed information.

   (This skill must, of course, be consistent with the maturity level of the child. However, all children, depending on their age, can help determine the best way for them to obtain answers to problems. Possible sources for the needed information must be listed, i.e., books, field trips, films, lectures, etc. Then the students may be asked to decide which way will provide information most quickly, but also with most vitality and reality.)

7. Teach students how to carry out an experiment with the materials available, if it is decided than an experiment is the best way to obtain the answer to a problem.

   (Experimentation at the elementary-school level should minimize the use of equipment and maximize the factor of activity, locating materials needed, and observing and reporting accurately the things that happen. Also, it should emphasize the need for more than one trial. As the student progresses through the science program, greater emphasis should be placed on the utilization of sophisticated equipment. However, the teacher must insure that students realize that equipment is purely a means to an end, not an end itself. Frequently, the purpose of the experiments is obscured because of equipment far more complicated than is needed.)

A number of other efforts have been aimed at identifying dimensions of performance for science instruction. Although as yet these efforts have not had great impact, they do indicate the concerns of science educators for articulating more understandable, and hence more attainable goals for the instructional program in science. It is unnecessary to emphasize the fact that "one cannot teach what one does not understand." Until the present time, however, elementary teachers have been expected to implement goals having platitudinous connotations.

It is likely that future efforts will be devoted to the further delineation of the dimensions of performance, and to the development of techniques for attaining them.

The Content of Elementary Science:

As stated previously, most of the earlier elementary-science programs emphasized the biological sciences. The instruction was oriented toward the "nature study" approach. Even at the present time, in an age when the physical sciences have remarkably advanced, the greatest emphasis in elementary science is still on the biological sciences. This fact is evidenced in many studies, including one involving a sampling of Minnesota schools (7). The report indicates that "although most of the teachers reported that equal emphasis was given to biological and physical science, their logs indicated that biological science topics were considered in a ratio of 3:1 to physical science topics. . . . " This statement is supported by the results of studies that were undertaken by the author and her husband in two of the larger school systems in Michigan (10, 12). The other supporting studies are far too numerous to mention here.

There are probably two reasons for the biological emphasis. One is the residual effect of the nature-study approach to elementary science. The second is the fact that most elementary teachers receive at least some training in the biological sciences in their pre-service experiences, but little in the physical sciences. This point will be discussed later in the paper.

In spite of current practices, it is generally accepted that a well-rounded program of elementary science should place equal emphasis on all areas of science, namely, the physical sciences as well as the biological sciences. The recognition of the need for equal emphasis is made clear by even a superficial review of the tables of contents of the most commonly used series of elementary-science textbooks. It is also evident in the many pamphlets and articles dealing with the desirable content of elementary science. Further, in a recent review of research in elementary-science education (27) the following list of "ten most essential units" of science was compiled from the responses of teachers: "electricity, living things, weather and climate, astronomy, simple machines, plants, animals, magnetism, conservation, and health." It can be noted that five of the ten areas are in the physical sciences; and five in the biological sciences. In an outline of science instruction in the California Public Schools (24) the following areas are listed for elementary science:

What Life Needs
Weather Changes
Sound

Gravity
Where We Get Our Energy
Balance of Nature
Elements, Compounds, and Mixtures
Earth, a Part of the Solar System
The Vastness of Space
Possibilities of Space Travel
Forces Operating on the Earth
Wise Utilization of Natural Resources
The Interrelationships of Living Things
Sun, a Source of Energy

An examination of this list indicates that only four of the suggested fourteen areas are biologically oriented.

The trend toward the recognition of the place of the physical sciences in the elementary science program is well-summarized by Nelson (22), who states:

"Certainly a single area such as insect-life or shell-collecting is not to be thought of as constituting a course of study; neither is a warped science program where biological science is taught to the exclusion of the physical sciences. The physical sciences are as important to the child of today as the study of nature was to the child of yesterday. This does not . . . [imply] that the biological sciences are to be forgotten. A . . . balance needs to be obtained in this respect, with a 70–30 balance in favor of physical science being maintained at the intermediate and upper grade level, and a 40–60 ratio at the kindergarten and primary levels."

The Sequence in Elementary Science:

Although there is a growing agreement concerning the proper distribution of the subject-matter content of elementary science, there is still much controversy concerning its *sequence*. Some researchers (17, 18, 19) have sought to determine the "ideal" grade placement of the various subject-matter topics and concepts of science in the elementary-school program. While their efforts have been diligent and admirable, it is becoming increasingly apparent that attempts to "grade-place" science subject matter in the elementary curriculum are indeed futile. There are a number of reasons for such a conclusion. The rapid accumulation of scientific information and the increasing sophistication of modern children render ephemeral within a short time many of the topics that are "grade-placed for once and for all." Also, the results of learning studies have shown that almost any topic or concept of science can be taught at any grade level, provided the teacher expects a depth of understanding consistent with the maturity of the elementary student.

The attempt to grade-place science subject matter also raises certain anomalies. Obviously, the science topics and concepts allocated to the kindergarten cannot be fully developed at that level, no matter what they may be. Additional study of the topics and concepts is bound to be needed if understanding is to be accomplished. Also, it is difficult to deny a third-grader the opportunity to explore an area

of science assigned to the sixth-grade merely because the level of understanding is fixed arbitrarily at the sixth grade. Consequently, it is obvious that a topic or concept of science may be included in the program of elementary science at several different grade levels.

Assuming that specific grade placement is rejected, one might suggest the alternative of teaching all areas of science each year during the elementary program. Such has been found to be undesirable in view of the time limitations and because of the superficial treatment that can be given to the areas. Hence, most organized elementary-science programs are designed around a spiral approach to the science subject matter. This plan for organizing the subject matter is claimed to offer a continuous, sequential program of science that is relatively free of "gaps" and overlap. One such spiral pattern (30) recycles the basic* units of science at three levels in the elementary curriculum. The three levels are Kindergarten-grade 2; grades 3–4; and grades 5–6. Each of the "basics" are dealt with once at each of these three levels. Thus the elementary student has experience with each of the basic units three times during the elementary-science program. The exact grade placement of the various units of science subject matter within each level is determined by the teachers in each elementary school.

In order to eliminate overlap and needless repetition in the teaching of the nine basic areas, a plan was devised whereby the *approach* to the units differs at each of these levels on the basis of the maturity of the children involved. For example, with the young, immature children at the K-2 level, the study of science is largely *descriptive*. The emphasis is placed on the study of the *characteristics* of the objects, materials and phenomena of science that they study.

In the middle grades (grades 3–4) the interests of children broaden and they begin to evidence curiosity about the *relationships* between themselves and their environments. Consequently, the emphasis in science instruction is placed on *utilization*, or "use and value" aspects of objects, materials and phenomena of science.

At the upper elementary levels (grades 5–6) the increasing maturity of the children is evidenced in their preoccupation with, "what makes it go?" At this level, the science program emphasizes the approach, "What makes it work?", "Why does it behave as it does?", and "What caused it to happen?" This approach is usually referred to as the *operational*, or *functional* approach.

Where such a spiral development has been used, the necessary *repetition of areas* of science (each being studied three times) has been accomplished. However, the desirable overlap of science subject

* The basic units include: Living Things; The Universe; Minerals; Rocks and Soil; Water; Weather and Climate; Air; Light; Sound; and Machines and Energy.

matter has been avoided by "maturing" the approach at the respective levels.

It should be made clear that the "level approach" described here is not "the order of the day" for all elementary science programs. Nevertheless, there is less emphasis on the grade placement of science subject-matter and increasingly greater emphasis on varying the *approach* to the teaching of elementary science in a manner consistent with the maturation of the elementary student.

The Organization of Elementary-Science Instruction:

Until recently, it was common practice in elementary schools to teach science in a manner described as "incidental teaching." For example, if a student brought a rock to school, the class might launch on a unit in earth science. Or, if another student discovered a bird's nest and brought it to class, the teacher might use the nest as a "kick-off" for a unit in bird study. While such an approach in arithmetic or language arts would be considered totally inappropriate, it was generally considered respectable for science teaching. The recent emphasis, however, on science education has placed this approach in disrepute. While few persons would challenge the value of some "spontaneous science lessons," it is now generally accepted that an effective science program for the elementary schools must be planned and implemented just as with any other area of instruction. This viewpoint is currently one of the most significant trends in elementary-science education.

Although the concept of the planned elementary science program is now generally respected, it is difficult to discern any agreement with respect to a time allotment for the planned instructional program. Some schools require that each day a specific number of minutes be devoted to science instruction. Others stipulate that a specific number of minutes per week must be devoted to science instruction. Usually the time allotment averages about 30 minutes per day. In many other systems, however, the time allotment for science instruction is left to the discretion of the classroom teacher. The time allotment factor has been responsible for many controversies. Some elementary educators believe that flexibility of scheduling is best accomplished in the self-contained elementary classroom. Many educators in this group are convinced that flexibility of scheduling best serves the objectives of science instruction and that a definite time allotment hinders the accomplishment of the desired goals of science instruction.

Other elementary educators disagree and query, "If a definite time is not set aside for science instruction, is it not likely that elementary teachers will avoid teaching it?" A few years ago, the answer to this

query might well have been affirmative. However, with the increased emphasis in recent years on the need for improved science instruction in the elementary schools, the neglect of science under any system of time allotment is becoming less common. Many administrators and school board members, in an attempt to retain the flexibility of the elementary classroom, and at the same time insure effective science instruction, are indicating to teachers, "We expect you to cover so many units of science with your children during this year and on the average devote so many minutes per week to science instruction. How the units are inserted into your weekly schedule is up to your professional judgment."

The preceding discussion presumes that most science instruction is provided by the regular elementary classroom teacher. Without doubt, this is the most common practice. Nevertheless, there is a growing belief that a single classroom teacher cannot be an expert in all subject-matter areas that are included in elementary-school instruction. Hence, in some school systems, usually the larger ones, the use of special teachers for science has been tried. There is much discussion from a philosophical point of view concerning this practice of using special teachers. The advocates claim that it is impossible for an elementary teacher to be trained adequately in all fields. Hence, since science is a highly specialized field in which developments are taking place at an explosive rate, an elementary teacher trained especially to teach science is needed to provide adequate science instruction for children. Those who prefer the self-contained classroom in which the "homeroom teacher" provides all instruction, claim that this arrangement provides a better social and emotional climate in which elementary-school children can work, and hence results in better learning.

At present, there is little empirical or research evidence to support or negate the use of special teachers for elementary science. However, at the time of this report, the American Association for the Advancement of Science is conducting a pilot study (29) dealing with the use of of special teachers for science and mathematics in the fifth and sixth grades. When the findings are available, they should have much significance for elementary science education.

The Use of Textbooks and Supplementary Materials in Elementary Science:

Since another paper in this series is devoted specifically to textbooks for elementary science, the discussion will be confined to the relationship of textbooks and supplementary materials to the theme of this report. It is most important to indicate here that elementary teachers are much less "tied" to the science textbook than is the case

with teachers of science in the junior and senior high schools. This may, of course, have advantages as well as disadvantages. In many schools, there is no single textbook or series of textbooks in use. Rather, a variety of textbooks of science from different publishers and of differing grade levels are available in each elementary classroom. These are used as reference materials, rather than as "required textbooks." The proponents claim that this practice provides for flexibility and for individual differences within the science program. In other schools, a single textbook or series of textbooks is used by all students. The proponents claim that this practice provides for continuity in the science program and eases the task of the busy elementary teacher. From discussions at professional meetings and from surveys in which the author has participated, it appears that the two practices are about equally popular.

In a number of schools, particularly in those that employ a variety of textbooks, there is a trend for supplying teachers with some type of guide for teaching science. Such a guide may be called, among others, a "science study guide," "course of study," "science outline," or "syllabus for elementary science." In some states, such as New York and California, in which there is a highly-centralized state department of public instruction, the guides are generally prepared and distributed by the state authorities. In other states in which there is less centralization, the guides may be prepared by science supervisors or by groups of elementary teachers especially trained and/or interested in science. In so far as usage is concerned, it has been found that teachers are more likely to use such guides if they are developed by teachers, rather than by supervisors.

In addition to textbooks and study guides, there is now a wide variety of supplementary teaching aids available to elementary teachers. These range from the vast numbers of "trade" books in science to the free and inexpensive aids available from industry and other organizations. A number of bibliographies listing these trade books and supplementary materials have been published for use by teachers. The supplementary materials are considered to be most useful for providing background information for teachers. In most cases their levels of reading difficulty are too high except for the superior students.

Teaching Techniques for Elementary Science:

The instructional patterns in most elementary schools are designed to conform with the physical and psychological characteristics of young children. Thus the organization of learning activities is less structured than in secondary schools or colleges. Children in the ele-

mentary school have short spans of attention and memory. Further, they are less capable of understanding and gaining insight into broad concepts and areas of knowledge than is the case with older children. This point is expressed by Thompson (31) who states, "The process of maturation . . . is inimitably tied up with ability to adjust, learn new things, and consolidate previously acquired knowledge into new concepts." Thus, the activities in an elementary classroom are based on relatively narrow units of work and more restricted concepts. Also, the focus of the teaching activity and the type of activity changes frequently. In elementary science instruction the most common learning activities are text reading and classroom discussion. This point is supported by the findings of Johnston's study (7) in which she states that ". . . text reading and discussion was the "most-used" science teaching method while field trips and laboratory work were the "least-used." The discussions based on text reading are, however, supplemented in most elementary classrooms by field trips, audio-visual instruction, and experiments and demonstrations. Unfortunately, however, independent activity of the "research and experimental" variety is emphasized less than most experts believe it should be.

There is no evidence that any one method for teaching elementary science is superior to another. Much research has been undertaken in efforts to determine *the* one best teaching technique. The findings seem to indicate that every accepted method for teaching elementary science is effective, if it is properly selected and used. The same finding applies to the various devices used in teaching elementary science, as indicated in the following statement from a review of research in elementary science (2):

"From a survey of the studies related to the use of sensory aids in the teaching of elementary-school science, it is difficult to make any generalizations with respect to the comparative values of sensory aids. However, the research seems to indicate that such devices . . . are helpful in developing interest and increasing a student's factual knowledge of science. An additional value is their help to the elementary teacher who may lack subject-matter background in the field of science."

Of all the different teaching techniques, the one most unique to science is experimentation. Obviously, such "experiments" are not of the high school or college variety. Probably they are better termed "experiences," or "activities," rather than experiments. Nevertheless, they may serve as problem-solving situations in elementary science, provided they are carried out properly. This viewpoint is well summarized by Craig (5) who states:

"Every classroom of the elementary school, including the nursery and kindergarten, is a laboratory where experimentation may be conducted. The materials can be simple, and in the main obtained in the community. Dishes, jars, sand,

soil, bottles, candles, drinking straws, magnets, dry cells, insulted wire, and seeds are illustrative of the kinds of materials which are useful in the classroom."

Elementary science experiments can be designed to answer children's questions, develop understandings of facts and principles of science, and perhaps most important, give practice in the performance skills listed on pages 5–8 of this report. However, they must be developed in such a way as to serve as a source of information, not merely "prove" or illustrate a point or fact already known.

The provisions of Title III of the National Defense Education Act are particularly significant for elementary science. The monetary support under Title III has enabled school systems to provide many elementary classrooms with science equipment they needed. Prior to the assistance provided by the NDEA, the only equipment available for science in many elementary schools was home-made apparatus, materials brought from home by the teacher or children, "dimestore" items, and discards from the junior and senior high schools. However, the NDEA monies have enabled many school systems to purchase larger and more expensive pieces of equipment that are needed for sophisticated instruction in elementary science. An "approved" list of equipment for purchase under the provisions of Title III of the NDEA is found in a publication entitled, *Purchase Guide for Programs in Science, Mathematics, and Modern Foreign Langauges.* The *Purchase Guide* is divided into three sections, namely, "Basic,"—the materials needed for a minimal program; "Standard"—the equipment which, when added to the basic list, will provide for a broader program; and "Advanced"—those materials recommended for a more specialized program. The NDEA "Basic" list for elementary science follows (4):

Elementary Science: Basic

Anemometer
Balance, Spring, Heavy Duty
Barometer, Aneroid
Beaker, Griffin, Low Form
Bell, Electric
Binocular, 4×
Boiler, Double
Buzzer, Electric
Clamps and Tongs
Compass, Magnetic, 1.5 cm
Compass, Magnetic, 4.5 cm
Electromagnet, Horsehoe Form
First-Aid Cabinet, with Supplies
Flask, Erlenmeyer
Flask, Florence, Flat Bottom
Globe, Terrestrial
Hot Plate, Electric, Three-heat Single Unit
Hot Plate, Single Unit
Kits
Lamp, Electric, Miniature
Lenses, Demonstration Set
Magnet, Bar
Magnet, Bar, Alnico
Magnet, Horseshoe
Magnet, Horseshoe, Alnico
Magnet, U-Shaped
Magnifier, Reading Glass
Meter Sticks
Microscope, Elementary
Net, Insect, Collapsible
Prism, Equilateral
Prism, Equilateral, Lucite
Receptacles for Miniature Electric Lamps
Rod, Glass
Spatula, Stainless Steel

Test Tubes, Borosilicate	Thermometer, Large, Wall
Thermometer, Centigrade, Fahrenheit, Combined Scale	Tools
Thermometer, Centigrade, $-10°$ to $+110°$	Tubing, Glass
	Tubing, Rubber and Plastic Volt-Ammeter, Battery Test Meter

It should be stated that the above list is not necessarily typical of what is found in most elementary schools. In fact, it will be some time before the majority of the elementary schools acquire even the basic NDEA list. Further, the opinions of specialists in elementary science are almost unanimous in stating that the values of the equipment depend on the extent to which the elementary students use it in collecting information. If the equipment is used for "effortless entertainment" the money and time are probably wasted.

Television and Elementary Science Instruction:

Educational television is a new and unique technique now under study for teaching elementary science. It is generally agreed that this technique has tremendous potential as a teaching medium. However, there are many questions still unanswered about its optimal use. Among these unanswered questions are these: Should ETV provide the entire instructional program for elementary science, or should it be supplemental? How long should an educational program last? What topics can be taught over ETV and which ones cannot? What is the relationship between the regular classroom teacher and the elementary science program on ETV? As yet there are no satisfactory answers. Yet, despite the unanswered questions and problems, most educators are optimistic about the possibilities of using educational television in one way or another in teaching elementary science. A research study (23) conducted in New York City, during which a series of science lessons were presented by ETV for grades K-2 and 3–4 elicited these findings:

1. Pupils' interest in their environment was greatly stimulated. They were also made more aware of science in their lives
2. The pupils' interest was reported to be high during as well as after the programs.
3. The programs were highly effective in increasing the children's fund of science information.
4. The series was reported as being extremely valuable to the teachers in showing them activities useful in their teaching programs in general.
5. The teachers considered the series to be excellent as a useful classroom aid.

It will be noted, however, that the findings are chiefly subjective rather than objective.

The current Midwest Project on Airborne Television Instruction (MPATI) is one of the most extensive projects ever undertaken with ETV. In brief, MPATI will be concerned with telecasting a number of courses, ranging from the early elementary to the college levels, via

video-tape recorders from an airplane circling above northern Indiana. The signals will cover a seven-state area. A series of programs in elementary science will be included in the course offerings. The feasibility of the technique for telecasting is still to be determined, since the programming does not begin until February 1961.

The Teacher of Elementary Science

It is common knowledge that the quality of any instructional program depends primarily on the qualifications of the teacher. This axiom applies to science teaching as well as to all other subject-matter areas. It is common knowledge also that elementary teachers are generally less adequate in their science training than in any other academic areas. A summary of investigations dealing with the science backgrounds of elementary teachers makes this point clear (2). The summary states:

> "These studies of the lack of subject-matter knowledge in science of prospective elementary teachers reveal that most of them do not possess an adequate knowledge of science to enable them to teach it effectively. While most prospective teachers have had good science backgrounds in high school, it would appear that they need some general survey courses on the college level to refresh and supplement their science knowledge."

An analysis of recent efforts for improving the pre-service and in-service training in science for elementary teachers yields some pertinent facts.

Pre-Service Training:

There appears to be a trend in teacher-training institutions toward offering broader, survey-type courses in science for the prospective elementary teacher. In the past, the usual college courses in science available for candidates for elementary teaching were the courses designed for science majors. There is considerable opinion that such courses are too specialized to meet the needs of elementary teachers who must teach *all* areas of science, not just "Vertebrate Anatomy," or "Chemistry I." It is naive to suggest that an elementary teacher should take the introductory courses in *all* the sciences and thus receive the breadth of training required. The credit limitations of the college programs for training elementary teachers make this solution unrealistic. Also, there is a general belief that the typical introductory courses in the science do not provide the breadth of understanding in, or develop the relationships among, the various science fields that an elementary teacher needs. It has been suggested, therefore, that the broader survey-type courses in science are most suitable for the pre-service experience of elementary teachers. The number and variety of such courses is increasing steadily. It is reasonable to postulate that the increase may be attributed partly to the "general education"

movement in the colleges. Many of the general education courses in science are being used as the basis of the pre-service experiences of the prospective elementary teacher. It is difficult, if not impossible, to show that these courses have provided a suitable solution to the pre-service training in science for elementary teachers. The efforts do indicate, however, that the problem is recognized by college and university officials, and that efforts are being made to find a solution.

Another related problem concerns the state certification requirements for elementary teachers. The following conclusion from a review of research (2) reveals some of the inadequacies already discussed:

> "A summary of the studies dealing with the training of prospective elementary school teachers in the field of science reveals a severe lack of subject matter courses in their backgrounds. One of the reasons for this inadequacy may be the fact that most states require very few science courses for certification of teachers. Likewise the requirements of most teachers' colleges, though somewhat higher than those of the states, are still quite lax with respect to the required science courses for the training of teachers."

It is doubtful that, at the present time, science educators can depend on the improvement of science backgrounds of teachers through state certification requirements. Rather, those interested in such improvements will need to undertake a "bootstrap operation," and provide more science courses designed for prospective elementary teachers in the college curriculum.

In-Service Training:

Even if the ideal program for the pre-service training of elementary teachers could be accomplished immediately in teacher-training institutions, there would still exist the need for helping the teacher "on the job." It is essential that in-service programs in science be developed for supplementing the pre-service programs. In essence, in-service programs service two functions, namely, (1) to supplement the inadequate backgrounds of teachers in the field, and (2) to bring the teacher up-to-date with respect to new science subject matter and methodology.

The enrollments in graduate courses in science for elementary teachers have been gradually increasing throughout the United States. Part of the increase is due to the "pressure" from local school boards and state certification departments. However, much has been motivated by the teachers' recognition of their inadequacies. It is significant to note that when colleges and universities have offered courses in science designed specifically for upgrading the experienced elementary teacher, enrollments have been substantial. It should be stressed that, with few exceptions, these courses are *science* courses, *not* "methods" courses or education courses. Ordinarily, they are of-

fered by science departments, and are designed specifically for the elementary teachers.

In many cases, the impetus for such courses has come from school administrators. Frequently a school system will request the services of a university in providing an instructor to offer a course within the school system and which is designed especially for the local situation.

A discussion of in-service programs would be incomplete without some consideration of the programs of the National Science Foundation. It is well known that most of the funds of the NSF are devoted to the support of training programs for secondary-school teachers. Recently, as a result of the growing recognition of the need for the in-service training in science for elementary teachers, a few NSF grants have been awarded for the support of in-service institutes and summer institutes for elementary administrators, supervisors, and teachers. It is generally accepted that the efforts of the NSF to improve secondary science instruction have been fruitful. There is reason to believe that support of elementary programs will be equally valuable.

Summary

The purpose of this paper has been to survey the current status of elementary-science education in the United States. The author was instructed to describe the current status, not to evaluate it. However, in summary, the author has taken the liberty of making a few admittedly subjective, evaluative statements.

First, it seems reasonable to state that "elementary science is here to stay." Even though it is the most recent addition to the elementary curriculum, its value is generally accepted. Assuming that its role is accepted, the issue with elementary science rests largely on the improvement of the program.

What factors are involved in the improvement of the program of elementary science? In the opinion of the author, there are four major problems that as yet remain unsolved. They are listed below:

1. Lack of direction.
2. Lack of order.
3. Lack of continuity.
4. Lack of adequately trained teachers.

In the past, the teaching of elementary science has been "hit or miss," and plagued with over-lap and "gaps." It would appear that improvement will depend on the accomplishment of the following:

1. The establishment of a basic core of subject-matter areas for presentation at this level. (It should be noted that this does *not* imply a static core of *facts*, but rather broad areas to be modified as new scientific information is discovered).
2. The establishment of a workable, understandable list of goals and objectives of instruction that can be understood and implemented by teachers.

3. The development of some system of "spiralling" science instruction to insure growth of understanding and continuity of teaching, without needless overlap.
4. The improvement of pre-service training programs in the colleges and universities, and the development of realistic courses in science for elementary teachers.
5. The development of suitable in-service programs in science for experienced teachers.

These accomplishments represent a large order. However, they are imperative if an effective program of science instruction is to be installed in the elementary schools.

Selected Bibliography

1. *A Program for Teaching Science*, Thirty-First Yearbook of the National Society for the Study of Education, Part I. Distributed by the University of Chicago Press, 1932. Pp. xii+364.
2. Buck, Jacqueline V. and Mallinson, George Greisen, "Some Implications of Recent Research in the Teaching of Science at the Elementary-School Level." *Science Education*, XXXVIII (February 1954), 81–101.
3. Chamberlain, William D., "Development and Status of Teacher Education in the field of Science for the Elementary School." A paper presented before the Annual Meeting of the National Association for Research in Science Teaching, Atlantic City, New Jersey, February 15, 1957. Pp. 5.
4. Council of Chief State School Officers, *Purchase Guide for Programs in Science, Mathematics, Modern Foreign Languages*. Boston: Ginn and Co., 1959. Pp. vii+336.
5. Craig, Gerald S., *Science in the Elementary School*, Number 12 in "What Research Says to the Teacher," Washington, D. C.: National Education Association, 1957. Pp. 33.
6. Crow, Lester D. and Crow, Alice, *Educational Psychology*. New York: American Book Company, 1948. Pp. xiv+599.
7. Johnston, Jane, "The Relative Achievement of the Objectives of Elementary School Science in A Representative Sampling of Minnesota Schools." An abstract of a paper presented at the Thirty-third Annual Meeting of the National Association for Research in Science Teaching, Chicago, Illinois, February 10–13, 1960. Pp. 2.
8. Kusian, Louis I., "Elementary Science in Connecticut, 1850–1900." A paper presented at the Thirty-second Annual Meeting of the National Association for Research in Science Teaching, Atlantic City, New Jersey, February 18–21, 1959, Pp. 7.
9. Mallinson, George Greisen, "State Requirements for Certification of Teachers of Elementary Science." *Science Education*, XXXIII (October 1949), 289–91.
10. Mallinson, Jacqueline Buck, "The Grand Rapids Study." *Science Education*, XLV (February 1961) (scheduled for publication).
11. Mallinson, George G. and Jacqueline V., "A Survey of the Program of Science Education," An unpublished mimeographed report to the Board of Education and Administration of the Grand Rapids Public School System, 1958. Pp. 41.
12. Mallinson, George G. and Jacqueline V., "Goals and Objectives for Science Teaching," Mimeographed report prepared for the Royal Oak, Michigan Public Schools. Undated. Pp. 11.
13. Mallinson, George G., and Jacqueline V., "The Academic and Professional Preparation of Teachers of Science," Chapter V in *Review of Educational Research*, XXVII (October 1957), 365–74.
14. Mallinson, George G., and Sturm, Harold E., "The Science Back-

grounds and Competencies of Students Preparing to Teach in the Elementary School." Science Education, XXXIX (December 1955), 398–405.
15. MALLINSON, GEORGE GREISEN, STURM, HAROLD E., AND PATTON, ROBERT E., "The Reading Difficulty of Textbooks in Elementary Science." *The Elementary School Journal*, L (April 1950), 460–3.
16. MATALA, DOROTHY C., AND MCCOLLUM, CLIFFORD G., "Science in the Elementary Grades," Chapter I in *Review of Educational Research*, XXVII (October 1957) 311–28.
17. MCCARTHY, FRANCIS WADSWORTH, "Age Placement of Selected Science Subject Matter." Unpublished doctoral dissertation, Harvard University, 1951.
18. MCCOLLUM, CLIFFORD G., "The Determination of Science Maturity as a Means of Improving the Program in Elementary Science." *The Science Teacher*, XX (October 1953), 238–40.
19. OXENDINE, HERBERT GRANTHAM, "The Grade Placement of the Physical Science Principle, 'Sound is Produced by Vibrating Material' in Relation to Mental Ages." Unpublished doctoral dissertation, Boston University, 1953.
20. MICHALS, BERNARD E., "The Preparation of Teachers to Teach Elementary School Science." A paper presented at the Thirty-third Annual Meeting of the National Association for Research in Science Teaching, Chicago, Illinois, February 10–13, 1960. Pp. 19.
21. PRUITT, CLARENCE M., "Elementary Science in English and American Schools." *General Science Quarterly*, XII (March 1928), 461–6.
22. READ, JOHN G., AND NELSON, PEARL ASTRID, "A View of Science Education —Review and Forecast." *Journal of Education*, CXLI (December 1958), Pp. 50.
23. REINER, WILLIAM B., "The Effectiveness of Television in Improving the Science Program of Kindergarten to Grade 4 Classes in New York City Public Schools." A paper presented at the Thirty-Second Annual Meeting of the National Association for Research in Science Teaching, Atlantic City, New Jersey, February 21, 1959. Pp. 4.
24. *Science and Mathematics Instruction in California Public Schools*, Prepared by the California Conference on Science and Mathematics in the Public Schools. Sacramento: California State Department of Education, 1958. Pp. 39.
25. *Science Education in American Schools*. Forty-Sixth Yearbook of the National Society for the Study of Education, Part I. Distributed by the University of Chicago Press, 1947. Pp. xii+306.
26. "Science Teaching in the Primary School," *Education Abstracts*, VII (September 1955), UNESCO Education Clearing House. Pp. 25.
27. SMITH, HERBERT A., WASHTON, NATHAN, MALLINSON, JACQUELINE BUCK, BOECK, CLARENCE, AND FRASER, THOMAS P., "Third Annual Review of Research in Science Teaching." *Science Education*, XXXIX (December 1955), 335–71.
28. *Studies in Teacher Education*, Science Teaching Improvement Program, American Association for the Advancement of Science, 1515 Massachusetts Avenue, N. W., Washington, D. C. March 1960. Pp. 19.
29. *Study on the Use of Special Teachers of Science and Mathematics in Grades 5 and 6*, Science Teaching Improvement Program, American Association for the Advancement of Science, 1515 Massachusetts Avenue, N. W., Washington, D. C. Undated. Pp. 15.
30. *Suggested Study Guide for Elementary Science*. Grand Rapids Public Schools, Grand Rapids, Michigan, 1958. Pp. 251.
31. THOMPSON, GEORGE G., *Child Psychology*. Boston: Houghton Mifflin Company, 1952. Pp. xxxiii+667.
32. VICTOR, EDWARD, "Why Are Our Elementary School Teachers Reluctant to Teach Science?" A paper presented at the Thirty-third Annual Meeting of the National Association for Research in Science Teaching, Chicago, Illinois, February 10–13, 1960. Pp. 16.

Science for Grades Seven, Eight, and Nine

Abraham S. Fischler

Harvard University, Cambridge, Massachusetts

Introduction

Is there any doubt that the science offerings in grades seven, eight, and nine can and should be improved? In an increasingly science-based society we have a great responsibility to all the children in these grades since this will be the last time many will study any science, particularly physical science. While approximately 85% of our high school students elect a course in biology after grade nine, less than 35% elect any course in the physical sciences.[1]

The impact which science has on our culture will certainly continue in the future. However, the rate of increase will depend in part on the desire of our citizenry to support scientific investigation. Science must be taught to all, and its importance must be understood by all. There is scarcely a personal or public issue today which is not in some way associated with the scientific enterprise; automation, nuclear energy, health, world food production and distribution, are but a few examples.

The intent of this paper is to appraise the existing situation in science for grades seven through nine, to reflect briefly on its background, to analyze the major difficulties in this area, and to propose a "plan for the future" for discussion.

Rise of "General Science"[2]

The term "general" as part of "general science" may be somewhat misleading in that science itself is general; it includes a number of scientific disciplines created by man within the framework of the scientific enterprise. It is this interrelationship which enables an individual to understand scientific generalizations more clearly. For purposes of clarity, however, we will use "general science" in its historic and accepted sense.

The beginning of the "general science" movement dates back to about 1900. At the turn of the Twentieth Century, a science course was organized at Springfield High School, Springfield, Massachusetts, for the ninth grade. This new course, it was hoped, would be more interesting and challenging than the course it replaced, would encourage students to take additional science courses, and also would give

[1] Koelsche, Charles L., Solberg, Archie H., *Facilities and Equipment Available for Teaching Science in Public High Schools 1958–1959*, Research Foundation, University of Toledo, Ohio, 1959, page 10.

[2] Fischler, Abraham, *Modern Science for the Junior High School*, Bureau of Publications, Teachers College, Columbia University, New York, 1961.

some scientific background to those who left school at the end of the ninth year. Such topics as: *Keeping Well, The House We Live In, Household Electric Appliances, Weather, Our Neighbors in Space,* and the most famous of all units, *The Springfield Water System,* were included. The titles of these topics indicate utilitarian and environmental approaches which have characterized "general science" courses to the present time.

About this time (1903) a committee representing the National Education Association and the Department of Secondary and Higher Education recommended a six-year unified secondary school program beginning with grade seven. Later, the Committee on Economy of Time in Education (appointed in 1907) recommended in their report of 1913 a six-three-three plan of organization. This was the beginning of the junior high school movement.

The term "junior high school" includes grades seven, eight, and nine, which may or may not be housed in one building. It was first developed as a separate organizational unit because of the building shortage. There was overcrowding of both the elementary and secondary levels, and it was thought that by removing the two upper grades from the elementary school and the lowest from the high school, the problem could be alleviated. It was also felt that since many pupils dropped out of school at the end of the eighth grade, some would be encouraged to remain in school for an additional year.

As there was no tradition associated with the junior high school, experimentation was encouraged and new curriculum patterns were tried out. "General science" fitted into this scheme since it was a relatively new subject and provided opportunity for the students in their first year of high school to experience an introduction to botany, chemistry, physics, zoology, and physiology. It was hoped that this type of course would serve as an orientation to the more advanced sciences and would have a guidance function as well. Although most courses were organized in this way, the trend was in the direction of the Springfield plan previously mentioned.

Some early textbooks, such as *A First Year Course in General Science* by Clara Pease written in 1915, were organized into three distinct areas, botany, chemistry, and physics. In many cases each section was written by a specialist in the particular field and there was little relationship among the three areas.

From the beginning, science educators writing in the *General Science Quarterly,* a publication which appeared in 1916, advocated a careful consideration of the student's home and community environment before determining the content of the "general science" course. The aims stressed were practical application of scientific concepts, learning of usable experiences, adherence to scientific accuracy, and

the training of pupils to think. This fitted in with the general aims of the junior high school. Emphasis was placed on the benefits which might be derived by the students if the program was designed to meet their particular needs.

Nation-wide policy reports also attempted to influence the development of "general science" programs during the period 1920 to 1950. Enrollment in high schools was increasing but the drop-outs were numerous; seventy per cent did not go beyond the sophomore year during the twenties and early thirties. Teachers of senior high school science felt that "general science" should provide preparation and stimulation for later courses in science.

The first of the three policy reports released during the period 1920 to 1950 was the "Reorganization of Science in the Secondary Schools" prepared by a committee of eminent science educators and published in 1920. The task of the Committee was to suggest science programs compatible with the *Seven Cardinal Principles of Education*. This report proposed that the subject matter of "general science" should be selected to a large extent from the student's environment and organized in large units which comprised smaller problems for students to investigate.

In 1932, a report written for the National Society for the Study of Education (commonly referred to as the *Thirty-first Yearbook*) was published. This study, entitled *A Program for Teaching Science* had a marked influence upon the entire field of science. It recommended that "general science" be taught in grades seven, eight, and nine and that a limited number of units, or topics, be included. The report stressed the importance of functional understanding of principles and generalizations (big ideas), scientific methods, and attitudes as they affect human behavior. Emphasis also was placed on development of an integrated course of study from kindergarten through ninth grade.

In 1947, a second yearbook entitled *Science Education in American Schools* was written for the National Society for the Study of Education. This report stressed the expanding role of science in programs of general education. It reemphasized many of the recommendations made in the *Thirty-first Yearbook*, and also included references and synopses of educational research carried on prior to 1946. For the junior high school, the Committee again recommended that science experiences be related to the pupil's every day living and that content be organized in large areas of human experience. Science was considered a social force as well as a method of investigation, and a field of knowledge which influenced every person.

Since 1950, numerous additional reports have been published which continue to advocate the aims and objectives mentioned in the previous reports.

The Pupils—Grades Seven, Eight, and Nine

Essential to a truly functional program of study, as is noted in these reports, is an understanding of the characteristics of these young adolescents. For the child of age twelve to fifteen, immersed in puberty, this is a particularly complex and rapid period of transition. Marked individual variations show in extremes of physical and emotional development. At this period, girls are approximately twenty months ahead of the boys. For the girls this period marks the time of rapid growth, onset of menstruation, and the social awareness of the opposite sex. For boys, it marks the beginning of their growth spurt, their interest in their own muscular development, and the onset of sex stimulation. Since muscular development is rapid, there may appear disturbances in motor coordination with awkwardness and restlessness.

Emotionally, this is a period of behavioral conflict. There is a desire to break away from close family ties and yet there is also the need for the security of the home. As pupils of this age frequently have violent likes and dislikes toward adults, they may often direct this antagonism toward the teacher. Adult approval or disapproval is not as important as approval of their peers. The desire for group identification is strong and they respond to the pressures of the group or "gang."

Although these children are beginning to learn the "niceties" of social relations, they usually feel insecure in their relationships with the opposite sex. The fact that girls mature earlier than boys may create some difficulties at this time unless guidance is adequate. An increasing self-consciousness and an attempt to imitate adult behavior, yet often seek the security of childhood, may lead to variable behavior which is confusing to adults.

Intellectually, students are rather well oriented in time and space. They have increasing ability to deal quantitatively with aspects of their environment. Since they now perceive causal relationships, and can acquire an increased understanding of cause and effect results, they may profitably engage in activities which include planning and predicting. Their ability to understand abstract words increases slowly and many concrete experiences are still needed to develop a basis for generalizations.

Junior high school children do need group identification and peer approval, since they do need to gain self confidence especially with the opposite sex. Group work and projects are effective methods which may be used in the science classroom to achieve these purposes. Group work also allows for individual differences, since within a given framework students could select problems that interest and motivate them.

Because of the basic characteristics of the early adolescent, the need for guidance is apparent. It is here that the teacher can make a definite contribution by his patient understanding and skillful assistance. By utilizing group activities as well as laboratory work, the teacher may have some time for this guidance function.

During the junior high school period, experiences should be provided to assist students to think in quantitative and abstract terms, and to form generalizations about themselves and their environment. Experiences in the classroom, the laboratory, or on field trips should be oriented toward this task and, whenever possible, a quantitative approach showing the importance of mathematics and its uses in science should be stressed.

Present Weaknesses

In order to build an effective science program for grades seven, eight, and nine, we must first recognize and analyze the weaknesses in our present set-up. This section will deal with the goals, the different school organizational patterns, and the tremendous task of the teacher.

1. *Restatement of Goals*

Statement of the objectives of the science program for this age group can be found in many sources. Unfortunately, these are usually stated in somewhat general language. Two examples are, "growth in scientific skills, attitudes, and appreciations," or "functional understanding of concepts, principles, and generalizations."

One of the reasons for the lag between what has been proposed by science educators and what is currently in practice is the inability of teachers to understand fully what is meant by these goals. If one looks at the aims of "general science" as practiced in most classrooms, it would appear to be the accumulation of scientific facts. One method of checking is to look at the type of test most teachers give their students. They are usually tests involving hardly more than the recall of information—tests in knowing, not in doing. There is little emphasis on the nature of science or the relation of science to society. There are few thought-questions involving the use of scientific principles to solve new and different problems. In addition there is a lack of laboratory and first-hand experiences.

A recent analysis of what teachers expected of their pupils in the seventh grade indicated that, in most areas, they expected the pupils to have increased ability to spell correctly, to carry out operations with numerals, and to read with some understanding. However, in science, students were not expected to *do* anything.[3] Until we are able

[3] Dr. George Mallinson, in a speech made at the National Science Teachers' Association Convention in Atlantic City, March 1959.

to write our goals and objectives in simple terms, in the form of statements which communicate a behavior that teachers can observe and attempt to measure, we shall not really make gains. As an example, How does the child perform? What questions does he ask about his environment to indicate that he is attaining an understanding of natural phenomena, an orientation to the physical world? If we were to spell this out, it might include some of the following:

1) Observes kinds, parts, functions.
2) Orders and relates things in terms of sequence, size, color, use, or general characteristics.
3) Matches, relates, compares, isolates, and makes aggregations.
4) Makes exceptions, finds discrepancies.
5) Uses his knowledge to make predictions.
6) Observes and talks about seasonal changes and response of plants and animals, position of stars due to rotation, animal population varying with climate, changes on surface of earth due to weathering and erosion.
7) Makes predictions on the weather based on an understanding of observable and relevant factors.
8) Asks critical and pertinent questions.
9) Seeks books, maps, globes, charts.
10) Gathers relevant information from many sources, correlates it, and makes defensible conclusions.

If science educators would state their goals in detailed behavioral terms and if teachers were trained to develop objectives using action verbs (as indicated above), this could be the first step in changing the present status of science instruction at this level; and possibly at all levels.

2. *Teacher-Organization*

As is well known, there are a variety of organizational patterns for students in grades seven, eight, and nine, and there are a variety of approaches in science for this particular group of grades.

Some students in grades seven and eight are in self-contained classrooms, housed in elementary school buildings. The teachers here are usually trained in elementary education, with little or no preparation in science. Time and equipment for needed first-hand experience are usually lacking. If science is taught at all, it is usually incidental and students read about it from a book. There are exceptions, of course, but hardly enough to compromise the validity of these generalizations.

The problem of teaching science in grade seven is somewhat different than in grades eight and nine in the junior high school. In most cases students come from a wide area. The socio-economic level varies as well as parental aspirations. These children are usually grouped together heterogenously in grade seven. This, as you might expect, adds to the dimension of the science teacher's task. In one town with which I am familiar, there is only one junior high school serving six

elementary schools. Since these elementary schools are located in various sections of this cosmopolitan community, each elementary school is a quite separate and independent body. Some of the schools have a good elementary science program while others have practically none. In order to "integrate" the children in the junior high school, the administration attempts, in the seventh grade, to have classes composed of students from all six elementary schools. Consequently, a wide range of previous experience, knowledge, and comprehension exists in each teaching group.

The time allotment for teaching science in the seventh and eighth grades varies throughout the country. Some children have no science in these grades but have five periods per week in the ninth grade. One pattern consists of two periods per week in grades seven and eight, and five periods in grade nine; another popular variation is five periods for one half year in grades seven and eight, and five periods in grade nine for a full year. The recommendations of science educators since 1932 have argued that science should be given equal status with other major subjects and should be scheduled for five periods per week in all three grades for the entire school year.

Classes tend to be larger in "general science" than in any other area of science. A study conducted by the United States Department of Health, Education and Welfare[4] found that the average class size in "general science" in their sample contained 31.1 students while the national average for biology was 27.7, chemistry 22.6, and physics 19.9. This means that if a "general science" teacher has five or six classes per day, he will meet approximately 150–180 students daily. In those schools offering "general science" in grades seven and eight for only two periods per week, a teacher may meet as many as 300 different children per week. In this situation it is almost impossible for a teacher even to get to know his students.

Many teachers of "general science" have split loads, also teaching either mathematics or physical education. Dr. Milton Pella[5] reported that only 30.3% of the "general science" classes were taught by full time science teachers, and 69.7 by part-time science teachers. 21.1% of the part-time "general science" teachers were responsible for some phase of physical education.

Due to his heavy teaching load, the science teacher in the junior high school finds little time for preparation of demonstrations, or for guidance of individual students. Not only does he lack time, but also the facilities and equipment necessary to do an adequate job. Usu-

---

[4] Brown, Kenneth and Obourn, Ellsworth, *Qualifications and Teaching Loads of Mathematics and Science Teachers in Maryland, New Jersey, and Virginia:* U. S. Government Printing Office, Circular 575, 1959, page 22.

[5] Pella, Milton O. *The Status of Science Offerings in Wisconsin Schools in 1955–56.* Madison, University of Wisconsin, 1956.

ally his room is poorly equipped for science with nothing more than a demonstration table. Laboratory equipment for individual and group work is very poor, if present at all.

Of a total of 855 schools studied, equipment and supplies for teaching "general science" were rated poor or fair in 78.6% and good in only 21.4%.[6]

In addition to the heavy teaching load and poor facilities, it is generally felt that a "general science" teacher does not have the same "prestige" as the teacher of biology, chemistry, or physics. This is true partly because there is no national or local organization of "general science" teachers, no professor of "general science" on the university campus, and no nation-wide group giving direction to this field. Many junior high schools have no science chairman; thereby placing the responsibility for supervision on the principal, who is always busy and often lacks competence in science.

We must also be aware that most teachers of "general science" have not been trained specifically for this task, but intended to become teachers either of biology, chemistry or physics. Since the teacher desires to teach in his area of competence, he usually spends from three to five years teaching "general science" and then succeeds either in "moving up" within his present system or in securing a position in another system teaching in the high school. Often after developing some competency, he leaves; thus the junior high school becomes the training ground for the senior high school. Dr. Conant[7] remarks on this exodus of good teachers from grades seven and eight to the senior high school in his latest book.

It is therefore understandable that few teachers wish to commit themselves to a career of teaching science in grades seven, eight, and nine. Yet, as Dr. Conant remarks,

Because of the transitional nature of these grades, teachers with an unusual combination of qualifications are needed. Satisfactory instruction . . . requires mature teachers who have both an understanding of children, a major characteristic of elementary school teachers, and considerable knowledge in at least one subject matter field. . . . Teacher training institutions have responsibility in this regard.[8]

In addition to different patterns of organization, varied time allotments for science and the problems of the science teacher of these grades, there exists the problem of actual material for teaching and learning. An examination of various textbooks illustrate that there is little agreement as to the number and placement of topics. They range from six to eighteen in any one grade. The topics are often unrelated, show little flexibility for individual differences, tend to be

---

[6] Koelsche, Charles L., Solberg, Archie, *op. cit.*, page 32.

[7] Conant, James B., *Education in the Junior High School Years*, Educational Testing Service, Princeton, New Jersey, 1969, page 35.

[8] Conant, James B., *ibid.*, page 13.

rather superficial, and omit new developments in science which might be included.

> In looking over the various textbooks, I was completely at loss as to what had motivated the choice of the particular concepts and the grades assigned for teaching them. From the viewpoint both of logical and psychological presentation of scientific ideas much was obviously wanting. In some instances, indeed, fundamental concepts were incorrectly presented, and in many more cases incompletely, so that on each regular test the class (of teachers) found it stimulating to criticize about ten such misstatements from both scientific and pedagogical points of view. . . . My primary objection to such texts is that most of the material is at best only nominal, i.e., learning by modernized rote merely the names of things—if even that. . . . There is evidently a determined effort, increasing with grade level, to teach "all about science," but not at all a hopeful desire to learn science as a way of understanding nature. What is worse, the same material is frequently repeated in consecutive grades with no obvious, cumulative progress or curricular relation. Why then are particular topics selected for certain grades? Are social objectives the dominating ones? What about scientific goals? Evidently any answer to this basic question depends upon one's own conception of science itself.[9]

It is hard to find a rationale for the present curriculum guides. There is little evidence or explanation of why certain areas are included and others omitted; the "how" and "why" of the guide is neglected, the interaction is not apparent. The preparation of teaching guides has often been another responsibility given to the teachers in addition to their normal duties. We have assumed that they have the competence, resources, and time to do an adequate job. We now know that this is largely impossible.

Modifications of the Science Offerings in Grades Seven, Eight, and Nine

Many of these weaknesses have been recognized by educators throughout the country and various approaches are being tried. One pattern is a block program where math and science are both taught by one teacher for a year, or even longer. On first thought, this seems to be a good idea. In practice, however, it has not been too successful. As in the previous patterns discussed, the teacher is the key to its success. In many cases the teacher is doing an inferior job of teaching in both areas, since he must concentrate on two preparations, and may have competence in only one area.

Another approach being tried in two New York communities is the "ungraded science" program in grades seven and eight. In this particular program, promotion is not dependent on achievement in the areas of science and math, but rather on achievement in language arts and social studies. Grouping is done by ability and interest in science with the result that able students in the seventh grade may be working with others in the eighth grade, all working on a particular prob-

[9] Seeger, Raymond J., *On Teaching "All About Science,"* manuscript copy, September 4, 1960, pages 3–4.

lem. As you might imagine, here too, the teacher is the real key to the success of the program. He must be trained in *all* branches of science, must understand child behavior, and must be operating in a functional laboratory.

Some communities are attempting to introduce a separate science in grades seven, eight, and nine—by separate I am referring to biology in grade seven, chemistry in grade eight, and physics in grade nine. If one looks at this program superficially, it appears to be desirable. However, in my opinion, it would be unwise. When a child looks at his environment he does not see it subdivided biologically, chemically, and physically; he sees a tree, an automobile, or the sun and clouds. Is the study of a tree biological, chemical, physical, or geological? If you study the soil in which the tree is growing and the process of transpiration as it affects the rainfall, this might be geological or even meteorological. If you study the living parts and functions, this is usually biological, but if you study the process of photosynthesis or oxidation, this might be chemical.

If we place biology in grade seven, chemistry in grade eight, and physics in grade nine, then such areas as meteorology, geology, oceanography, and other areas might be completely neglected. It is important for students to realize that these areas involve cross disciplines and that today a person cannot be a biologist without at least knowing organic chemistry and bio-chemistry as well as an understanding of physical principles.

Students should see the relationship between the various disciplines within the scientific enterprise and not be forced to deal only with separate disciplines which are man-made. Why introduce these artificial barriers to all the children when ninety per cent of these will not be engaged in the field of science?

> Teaching specific topics or skills without making clear their contexts in the broader fundamental structure of a field of knowledge is uneconomical in several deep senses. . . . Such teaching makes it exceedingly difficult for the student to generalize from what he has learned to what he will encounter later. . . . Learning that has fallen short of a grasp of general principles has little reward in terms of intellectual excitement. . . . To create interest in a subject is to render it worth knowing, which means to make the knowledge gained usable in one's thinking beyond the situation in which the learning has occurred. . . . Organizing facts in terms of principles and ideas from which they may be inferred is the only known way of reducing the quick rate of loss of human memory.[10]

Although the above refers to special disciplines, I feel its application is equally pertinent to the field of science in its entirety.

It will be years before elementary science reaches a level where we may expect all children to be receiving an adequate science education by grade six. Therefore grades seven, eight, and nine provide the

[10] Bruner, Jerome S., *The Process of Education*, Harvard University Press, Cambridge, Massachusetts, 1960, pages 31–32.

last, and often only, opportunity for most students to gain an understanding of the nature of the scientific enterprise and the role of the scientist, the interrelations of science and society, the impact of technology on our industrial society, the unifying concepts which unite all the separate science disciplines, and career opportunities.

Another approach being tried along these lines is the introduction of biology or earth science in grade nine for the academically able student. This too has met with varying degrees of success. Brandwein[11] reports that of the number of students taking biology, earth science, or chemistry in grade nine, he found only thirty-five per cent of those who had had earth science in grade nine, forty per cent of those who had had biology and thirty per cent of those who had had chemistry were planning to take three more years of science as compared with eighty-five per cent of the "controls" who had had "general science" in grade nine.

Brandwein also reveals that the "maturity or age of students makes a difference. Students in the tenth, eleventh, and twelfth grades achieve higher grades than do their younger counterparts of equivalent I.Q., reading, and mathematics test scores who take the same course in the ninth grade." Of those taking biology and chemistry in the ninth grade "seven out of ten of these able students scored below 80% on the achievement scale . . . ." The comparable students who took biology in the tenth grade and chemistry in the eleventh grade after "general science in the ninth grade, seven out of ten achieved scores above 90%."[12]

A look at the British pattern might be helpful at this point. In British grammar schools "general science" is usually offered in Forms I and II (roughly equivalent to our grades seven and eight) for the most able students. This is usually followed by three years of study in biology, chemistry and physics, each meeting an average of three times per week. This includes both lecture and laboratory sections. This developmental program, unlike our layer-cake pattern of biology, chemistry, and physics for one year each, is built upon a broad and generalized foundation in general science.

Much more research is necessary to determine whether, and in what ways, the substitution of a particular science for even ninth grade science is beneficial for the students taking the course.

Proposal for the Future

Thus far our analysis of the present status of science in grades seven, eight and nine reveals many salient features to be met—

[11] Brandwein, Watson, Blackwood, *A Book of Methods*, Harcourt, Brace, and Company, New York, 1958, page 324.

[12] Brandwein, Watson and Blackwood, *ibid.*, page 325.

1) Restatement of goals
2) Understanding of the young adolescent
3) Questionable science in grades one through six
4) Different time allotments
5) Heavy teaching load
6) Poor equipment and facilities
7) Curriculum without focus
8) Many inadequately prepared teachers

Now, since we are concerned with the feasibility of a nation-wide study in this area, I should like to propose a possible program for your discussion.

I feel a nation-wide effort must be made in this area. To accomplish this end, four or five independent, yet cooperating groups might be organized in various universities situated in different parts of the country. These groups would utilize the knowledge and experience of local science educators, scientists, psychologists, and teachers in the local school systems who are familiar with the environment and needs of the children in their area. Each group should have a director who, as part of a board of directors, would help set policy for the independent groups, insure better communication and avoid excessive duplication.

The main purpose of each group would be the developing of teaching units. (*Note* the words teaching unit.) These units would contain the rationale in detail, goals in behavioral terms, immediate objectives from science as well as scientific inquiry. They would contain activities, possible approaches, evaluation techniques, enrichment activities, and any other information which is desirable or pertinent. Based on the local environment, available resources, and the needs of the children, each group would choose its own areas to develop. Cooperative analysis and planning under the nation-wide committee would detail the general topics and emphasis of the units; thus consistency and coverage would be provided along with diversity of context. These units would be school-tested, evaluated, and reworked. Each local system would secure these units, modify them for their own individual needs, and organize them into a three year sequence.

Since we must rely primarily upon those teachers now in our schools, the teaching unit would seem to be a more effective tool than any textbook. Teaching units with teachers' manuals, would serve as an immediate aid to the teacher giving him not only content, but also specific suggestions regarding objectives, methodology and evaluation.

One possible organization of the content might be the one recommended in the *Policies for Science Education* report written for the Science Manpower Project at Teachers College, Columbia.

SEVENTH GRADE—THE ENVIRONMENT AND HUMAN NEEDS

I. The Earth in Space
II. The Atmosphere
III. Water Resources
IV. Biological Resources

EIGHTH GRADE—USE AND CONTROL OF ENERGY

I. Structure of Matter
II. Transformation of Matter
III. Man and Machines
IV. The Body and How it Works

NINTH GRADE—FRONTIERS OF SCIENCE

I. Our Atomic World
II. Frontiers of the Earth
III. Maintaining Body Health
IV. Science and Change[12]

Note that this recommendation includes only four major areas per year, each centered about one theme. The teacher is encouraged to allow students to explore each area in depth, raise problems, find answers, and conceptualize. A unit is never "finished," and in the study of each unit, pupils are encouraged to look at themselves in relation to their environment and to the world and its problems. Since the program for each grade includes areas from several disciplines of science, the cross-field application of information and concepts is encouraged, and the unity of science is exhibited.

Articulation with the elementary school can be reached more easily since students would be encouraged to continue from where they left off and pursue the area to their full capabilities. For example: in the area of water resources some students might be considering the water cycle, others might be ready to start with the chemistry of water including water as a solvent, and still others might be encouraged to look at water as a necessity for life. However, all should be developing growth in their ability to understand science—both as a product and as a process.

The teaching units also may be organized around a number of major themes which appear repeatedly in science. Several examples are:

1. Science is a *process*, or operation, by which man attempts to establish patterns describing the world.
2. Man seeks an orderly world to permit him to anticipate or predict future events.
3. Since our patterns or models of how the world works are made by men, the existing ones are limited in scope and precision and will be replaced by more useful descriptions.
4. To assist us in exploring the consequences of certain propositions or models, we often use mathematical systems for clarity.

[12] Fitzpatrick, Frederick L., editor, *Policies for Science Education*, Bureau of Publications, Teachers College, Columbia University, New York, 1960, page 126.

5. We seek to know what happens if naturally occurring conditions are changed somewhat—this leads to exploratory observations and experimentation.
6. Scientific work is highly creative, like poetry, art, literature or musical composition; only a few will make major contributions, but all will benefit from their results.[14]

Such pervasive themes as these will serve to give continuity and structure to the science program. Also, they will aid in the selection of efficient contextual material, or experiences.

Whatever the organization, certain criteria must be kept in mind. The content should be of interest to the pupils; should allow for first-hand experiences, and should be presented in a logical sequence so that repetition on the same level of sophistication is avoided and pupils do not comment, "Oh, we *had* that before." Time should be allowed for pupils to pose and solve problems, and to explore an area to their fullest capabilities. The ultimate outcome should be pupil behaviors which demonstrate an understanding of the major themes.

But the preparation of materials for the teacher (units, teachers' manuals, and possibly special teaching aids) does not assure that these materials will be used, or used effectively, by teachers. Of all the science teachers, those for grades seven, eight, and nine are generally most in need of scientific knowledge. In addition, because their pupils are undergoing unique emotional and developmental adjustments, these teachers must examine carefully the impact of their instructional procedures on the pupils. Therefore, a major long-term teacher training program with specific objectives is essential.

This would be accomplished through the development of academic year institutes and summer institutes for "general science" teachers recommended by their respective principals and superintendents, who would indicate in advance that these people would have adequate time to function effectively as supervisors or helping teachers upon their return. Final selection of teachers might be shared by the colleges and the schools. By having the local systems commit themselves in advance, we are developing the beginning of a chain reaction. The teachers who gain this training will be in a position, upon their return, to help other teachers develop similar competency. This might be done during in-service training or through local courses. Having in the building a teacher with adequate training might encourage others to seek help and advice. Locally, the individual would be responsible for helping teachers develop competency in the teaching of the science units developed by these aforementioned groups.

This proposed approach would help give direction to the teacher of these grades, give him the self-satisfaction which he does not now

[14] Watson, Fletcher, "An Approach to Science Curricula in the Elementary Schools," *Frontiers of Science*, Oklahoma City, December, 1959.

have, create a supervisory role for the more competent career-minded individual, and set a pattern for the training of teachers.

Dr. Conant points out the necessity of educating local school boards to the need for hiring competent people at this level, for supplying them with adequate materials and facilities, and the commitment to keep them there once they reach a high level of productivity.

Summary

This paper attempted to relate "general science" to the purposes of the junior high school and the needs of the young adolescent. Also it attempted to illustrate current practices, different problems, raise questions, and offer one possible solution to our current crisis.

Questions and issues still remain. In order to focus attention, a few are listed below:

1) How can an adequate supply of science teachers be maintained?
2) What pattern of training should a teacher receive who is preparing to teach science in grades seven, eight, and nine?
3) How can competent leadership be developed both locally and nationally to give direction and prestige to these teachers?
4) How can present teachers be up-graded when so many are teaching in more than one area?
5) Upon what criteria should the program be structured?
6) On what basis should the sequence be organized so that it articulates with the emerging elementary school program and the high school program?
7) Who should be responsible for curriculum development for grades seven, eight, and nine?
8) Should separate labeled sciences be offered in grades seven, eight, and nine?
9) Should the science prone and academically able student be encouraged to take biology or earth science in the ninth grade?
10) What is the place of laboratory work in grades seven, eight, and nine?
11) How can adequate facilities in science be increased?

EARTH'S DUST CLOUD CAME FROM MOON

The dust cloud that encircles the earth several thousand miles out in space is formed of dust scattered from the moon when it is hit by meteorites, a U. S. scientist suggested.

Dr. Fred L. Whipple of Harvard College Observatory, director of the Smithsonian Astrophysical Observatory, Cambridge, Mass., said that space experiments should "readily" show whether or not his theory of a lunar origin for the dust cloud is correct.

The existence of a high concentration of interplanetary dust orbiting the earth has been indicated recently from rocket, satellite and space probe observations having instruments that detect the sounds the dust particles make when hitting the vehicle's surface.

Of four possible explanations for the origin of the dust cloud, Dr. Whipple believes that the lunar theory is the most "tenable." From this theory, a generally eastward motion of the particles in the dust cloud is predicted. This motion could be detected from space experiments.

Compared to the density of true interplanetary space, the concentration of dust particles in the cloud surrounding the earth is perhaps 100,000 times as high.

Summer Science Training Programs in 1961 for High-Ability Secondary School Students

Introduction

Almost 7,000 superior secondary school students are being provided with the opportunity to obtain tuition-free science training during the summer of 1961. The National Science Foundation, through its Summer Science Training Program for Secondary School Students, is making available to students of high ability—our potential scientists—educational experiences in science and mathematics beyond those normally available in high school courses, for the purpose of accelerating their scholarly development. Some 158 cooperating colleges, universities, and nonprofit research organizations are developing special programs and using their own faculties to provide instruction in scientific content and method. The Foundation program is intended to supplement previous limited-scale efforts and to encourage new efforts, public and private, in providing this type of summer training.

Programs being offered are of two main types. Though there is some variation with the discipline being studied, the type of program most frequently encountered stresses lectures, quizzes, supervised study periods, laboratory work, and field trips centered around one or more areas of science. The other program type gives the student real research experience by enabling him to work on a project of appropriate scope under the guidance of experienced scientists. Some of the programs combine elements of both types. The individual programs vary in length.

Financial Aid for Participants

Participant support will be limited to an amount equivalent to a maximum of 50% of the estimated subsistence and travel costs of the students. On this 50% basis, boarding programs include partial support for board, room, and travel; for commuters, the partial support usually includes carfare and lunches. This money may be variously apportioned to the different students, at the discretion of the director of each program, but will in no case exceed, for any one student, the actual amount required for board, room, and travel. Experience indicates that many students are willing to pay their own expenses, in full or in part, to secure the benefits of this training. By restricting participant support on this basis, the Federal funds available for this program will enable more students to participate.

Qualifications

Admission to the training programs will be determined by the sponsoring institution, NOT by the National Science Foundation. In general, selection will be based upon scholastic ability, scientific motivation, and the completion of of specified high school courses in science and mathematics. Students now in the 10th, 11th, and 12 grades are eligible. It is expected that the great majority of students will have completed their sophomore or junior years.

Inquiries and Applications

For further details, inquiries should be addressed to the Director of the program of specific interest. Application forms should be obtained from the Director, NOT the National Science Foundation.

SUMMER SCIENCE TRAINING PROGRAMS FOR HIGH-ABILITY SECONDARY SCHOOL STUDENTS

Alabama

Auburn University; *Life Sciences* (*includes research*); 6 weeks beginning June 12; Joseph T. Hood, Department of Agronomy and Soils, Auburn. (Boys only, 11th and 12th grades)

TUSKEGEE INSTITUTE; *Biology, Chemistry, Mathematics (includes research)*; 10 weeks beginning June 5; B. D. Mayberry, Division of Plant and Soil Science, Tuskegee Institute. (10th, 11th, and 12 grades)

Alaska

UNIVERSITY OF ALASKA; *Multiple Sciences;* 3 weeks beginning August 6; William S. Wilson, Head, Department of Chemistry and Chemical Engineering, College. (9th, 10th, and 11th grades)

Arizona

ARIZONA STATE COLLEGE; *Mathematics*, 5 weeks beginning June 12; J. Harvey Butchart, Chairman, Department of Mathematics, Flagstaff. (11th grade)

UNIVERSITY OF ARIZONA; *Physics, Mathematics (includes research)*; 10 weeks beginning June 13; Henry Freiser, Department of Chemistry, Tucson.

Arkansas

AGRICULTURAL, MECHANICAL AND NORMAL COLLEGE; *Biology, Chemistry, Mathematics, Physics;* 5 weeks beginning June 5; Rufus L. Caine, Director, Division of Natural Sciences, Pine Bluff. (11th and 12th grades)

SOUTHERN STATE COLLEGE; *Mathematics;* 6 weeks beginning June 5; John L. Chapman, Chairman, Division of Natural Science, Magnolia. (11th grade)

California

UNIVERSITY OF CALIFORNIA—BERKELEY; *Mathematics;* 6 weeks beginning July 3; Frantisek Wolf, Department of Mathematics, Berkeley. (10th, 11th, and 12 grades)

UNIVERSITY OF CALIFORNIA—BERKELEY; *Multiple Sciences (includes research)*; 9 weeks beginning June 26; Howard A. Shugart, Department of Physics, Berkeley. (Grades 9 through 12)

UNIVERSITY OF CALIFORNIA—DAVIS; *Microbiology (includes research)*; 6 weeks beginning June 13; Moshé Shifrine, School of Veterinary Medicine, Davis.

UNIVERSITY OF CALIFORNIA—SCRIPPS INSTITUTION OF OCEANOGRAPHY—LA JOLLA; *Oceanography, Marine Biology (research)*; 10 weeks beginning June 19; Norris W. Rakestraw, Graduate Division, La Jolla. (10th grade)

UNIVERSITY OF CALIFORNIA—LOS ANGELES; *Mathematics;* 6 weeks beginning June 19; Clifford Bell, Department of Mathematics, Los Angeles. (11th grade)

CHAPMAN COLLEGE; *Chemistry;* 9 weeks beginning June 26; Peter Coad, Head, Division of Natural Sciences, Orange. (12th grade)

COLLEGE OF THE HOLY NAMES; *Microbiology;* 6 weeks beginning June 26; Sister Mary Baptista, Department of Science, Oakland. (Girls only—11th and 12th grades)

COLLEGE OF THE PACIFIC; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning June 12; Jesse S. Binford, Jr., Department of Chemistry, Stockton. (10th and 11th grades)

COMMITTEE FOR ADVANCE SCIENCE TRAINING; *Biomedical Sciences (research)*; 10 weeks beginning June 26; Harry Sobel, 700 State Street, Los Angeles. (Commuting students only)

HUMBOLDT STATE COLLEGE; *Biology, Chemistry, Mathematics, Physics;* 4 weeks beginning July 31; John E. Butler, Department of Biological Sciences, Arcata. (11th grade)

LONG BEACH STATE COLLEGE; *Chemistry (research)*; 9 weeks beginning June 19; Darwin L. Mayfield, Department of Chemistry, Long Beach. (Grades 11 and 12)

SAN JOSE STATE COLLEGE; *Multiple Sciences;* 6 weeks beginning June 26; Wilbur Sprain, Department of Physical Sciences, San Jose. (Commuting students only—10th, 11th, and 12th grades)

UNIVERSITY OF SANTA CLARA; *Biology, Chemistry;* 6 weeks beginning June 19; Arthur T. Phelps, Director of Teacher Education, Santa Clara. (Commuting students only—11th grade)

Colorado

COLORADO COLLEGE; *Biology, Chemistry, Mathematics, Physics;* 8 weeks beginning June 19; Richard G. Beidleman, Department of Zoology, Colorado Springs. (11th grade)

COLORADO SCHOOL OF MINES; *Chemistry, Geology;* 6 weeks beginning July 10; James L. Hall, Department of Chemistry, Golden. (11th and 12th grades)

UNIVERSITY OF DENVER; *Multiple Sciences* (*research*); 9 weeks beginning June 19; R. B. Feagin, Research Physicist, Denver Research Institute, Denver. (11th and 12th grades)

Connecticut

AMERICAN METEOROLOGICAL SOCIETY (at Loomis School); *Physics and Meteorology* (*includes research*); 7 weeks beginning June 25; Vincent J. Schaefer, Loomis School, Windsor. (Boys only—11th grade)

UNIVERSITY OF BRIDGEPORT; *Biology, Chemistry, Physics;* 7 weeks beginning June 25; Earle M. Bigsbee, Chairman, Department of Physics, Bridgeport. (11th grade)

SOUTHERN CONNECTICUT STATE COLLEGE; *Multiple Sciences;* 6 weeks beginning July 5; Edward M. North, Department of Physics, New Haven. (11th and 12th grades)

District of Columbia

GEORGE WASHINGTON UNIVERSITY; *Multiple Sciences* (*includes research*); 4 weeks beginning July 5; Martin A. Mason, Dean, School of Engineering Washington. (Commuting students only—11th and 12th grades)

HOWARD UNIVERSITY; *Biology, Chemistry, Physics* (*research*); 8 weeks beginning June 26th; Herman R. Branson, Head, Department of Physics, Washington. (10th and 11th grades)

THE JOINT BOARD ON SCIENCE EDUCATION (AMERICAN UNIVERSITY); *Multiple Sciences* (*research*); 8 weeks beginning June 27; Leo Schubert, Chairman, Department of Chemistry, American University, Washington. (Commuting students only—11th grade)

Florida

FLORIDA STATE UNIVERSITY; *Mathematics;* 6 weeks beginning June 26; Eugene D. Nichols, Department of Mathematics Education, Tallahassee. (11th grade)

UNIVERSITY OF FLORIDA; *Multiple Sciences* (*includes research*); 8 weeks beginning June 19; Luther A. Arnold, College of Education, Gainesville. (11th grade)

ROLLINS COLLEGE; *Mathematics;* 6 weeks beginning June 18; Bruce B. Wavell, Department of Mathematics, Winter Park. (Boys only—10th, 11th, and 12th grades)

UNIVERSITY OF MIAMI, THE MARINE LABORATORY; *Marine Sciences* (*research*); 9 weeks beginning July 19; C. P. Idyll, Chairman, Department of Marine Sciences, Miami. (Boys and girls eligible, living accommodations for boys only—11th and 12th grades)

UNIVERSITY OF MIAMI; *Mathematics;* 6 weeks beginning June 19; J. H. Curtiss, Chairman, Department of Mathematics, Coral Gables. (Commuting students only—10th and 11th grades)

STETSON UNIVERSITY; *Mathematics;* 8 weeks beginning June 18; Harland C. Merriam, Department of Education, De Land. (11th grade)

Georgia

EMORY UNIVERSITY; *Astronomy, Chemistry, Mathematics, Earth Sciences;* two sessions beginning June 12 (4 weeks and 5 weeks); James G. Lester, Chairman, Department of Geology, Atlanta. (11th and 12th grades)

UNIVERSITY OF GEORGIA; *Multiple Sciences* (*includes research*); 6 weeks beginning June 12; T. H. Whitehead, Department of Chemistry, Athens. (11th grade)

Hawaii

UNIVERSITY OF HAWAII; *Multiple Sciences (research)*; 7 weeks beginning June 19; Donald C. McGuire, College of Agriculture, Honolulu. (Must be residents of the State and must be responsible for own housing in Honolulu—grades 10 and 11)

Illinois

EASTERN ILLINOIS UNIVERSITY; *Biology, Chemistry, Mathematics, Physics;* 8 weeks beginning June 12; Weldon N. Baker, Department of Chemistry, Charleston. (10th and 11th grades)

UNIVERSITY OF ILLINOIS; *Engineering;* 6 weeks beginning June 12; Jerry S. Dobrovolny, Head, General Engineering Department, Urbana. (11th grade)

NORTHERN ILLINOIS UNIVERSITY; *Chemistry;* 8 weeks beginning June 19; Virginia M. Schelar, Department of Chemistry, DeKalb. (11th and 12th grades)

NORTHWESTERN UNIVERSITY; *Engineering;* 5 weeks beginning July 2; F. G. Seulberger, Technological Institute, Evanston. (11th grade)

SOUTHERN ILLINOIS UNIVERSITY; *Multiple Sciences (includes research)*; 6 weeks beginning June 19; Howard G. Applegate, Department of Botany, Carbondale. (11th and 12th grades)

WESTERN ILLINOIS UNIVERSITY; *Biological Sciences (includes research)*; 8 weeks beginning June 12; Eugene Pergament, Department of Biological Sciences, Macomb. (10th, 11th, and 12th grades)

Indiana

BUTLER UNIVERSITY; *Chemistry, Mathematics, Physics;* 7 weeks beginning June 16; William H. Bessey, Department of Physics, Indianapolis. (Commuting students only—11th grade)

INDIANA UNIVERSITY; *Multiple Sciences (includes research)*; 2 weeks beginning June 18 and 6 weeks beginning July 3; Paul Klinge, Coordinator for School Science, Bloomington. (11th grade)

MANCHESTER COLLEGE; *Chemistry;* 8 weeks beginning June 12; Harry R. Weimer, Chairman, Science Division, North Manchester. (Grades 10, 11, and 12)

UNIVERSITY OF NOTRE DAME; *Mathematics;* 7 weeks beginning June 16; Arnold E. Ross, Head, Department of Mathematics, Notre Dame

PURDUE UNIVERSITY; *Biology (includes research)*; 8 weeks beginning June 19; Richard C. Dobson, Department of Entomology, Lafayette. (11th grade)

Iowa

SIMPSON COLLEGE; *Biological Sciences;* 6 weeks beginning June 12; Jack L. Carter, Chairman, Department of Biology, Indianola. (11th grade)

STATE UNIVERSITY OF IOWA; *Multiple Sciences (includes research)*; 8 weeks beginning June 12; Robert E. Yager, Department of Science Education, Iowa City. (10th and 11th grades)

Kansas

KANSAS STATE TEACHERS COLLEGE; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning June 5; Otto M. Smith, Director of Science Institutes and Research Studies, Emporia. (12th grade)

UNIVERSITY OF KANSAS; *Multiple Sciences (includes research)*; 3 weeks beginning June 18; Robert W. Baxter, Department of Botany, Lawrence. (10th, 11th, and 12th grades)

Kentucky

ASBURY COLLEGE; *Biology, Chemistry, Physics;* 8 weeks beginning June 5; J. Paul Ray, Department of Chemistry, Wilmore.

MURRAY STATE COLLEGE; *Biology, Chemistry, Mathematics, Physics;* 8 weeks

beginning June 12; W. E. Blackburn, Head, Department of Chemistry, Murray. (10th, 11th, and 12th grades)

WESTERN KENTUCKY STATE COLLEGE; *Biology, Chemistry, Physics, Mathematics;* 8 weeks beginning June 12; Tate C. Page, Director, Division of Teacher Education, Bowling Green. (11th grade)

Louisiana

LOUISIANA POLYTECHNIC INSTITUTE; *Multiple Sciences;* 9 weeks beginning June 5; William R. Higgs, Department of Geology, Ruston. (11th grade)

LOUISIANA STATE UNIVERSITY; *Marine Biology* (*includes research*); 3 sessions, 3 weeks each beginning June 5; Harry J. Bennett, Department of Zoology, Baton Rouge. (9th, 10th, and 11th grades)

LOUISIANA STATE UNIVERSITY; *Physical Sciences, Mathematics* (*includes research*); 9 weeks beginning June 9; John F. Christman, Department of Chemistry, Baton Rouge. (11th grade)

NORTHWESTERN STATE COLLEGE; *Biological Sciences;* 9 weeks beginning June 5; Richard Garth, Department of Biological Sciences, Natchitoches. (10th and 11th grades)

Maine

ROSCOE B. JACKSON MEMORIAL LABORATORY; *Biology* (*research*); 10 weeks beginning June 23; John L. Fuller, Assistant Director (Training), Bar Harbor. (10th, 11th, and 12th grades)

Maryland

UNIVERSITY OF MARYLAND; *Multiple Sciences* (*research*); 13 weeks beginning June 15; Howard Laster, Department of Physics, College Park. (Commuting students only—10th, 11th, and 12th grades)

MORGAN STATE COLLEGE; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning June 26; John W. King, Department of Biology, Baltimore. (10th, 11th, and 12th grades)

Massachusetts

AMERICAN ACADEMY OF ARTS AND SCIENCES (at Thayer Academy, Braintree); *Biology, Chemistry, Mathematics, Physics;* 10 weeks beginning June 19; William Stergios, Head, Science Department, Thayer Academy, Braintree. (Commuting students only—11th grade)

ASSUMPTION COLLEGE; *Mathematics;* 6 weeks beginning June 26; Alfons J. van der Linden, Chairman, Mathematics Department, Worcester. (Boys only—11th and 12th grades)

NORTHEASTERN UNIVERSITY; *Biology, Medical Sciences;* 6 weeks beginning June 25; Charles M. Goolsby, Department of Biology, Boston. (Boys only—11th and 12th grades)

WORCESTER FOUNDATION FOR EXPERIMENTAL BIOLOGY (at Saint Mark's School, Shrewsbury); *Biology* (*research*); 9 weeks beginning June 18; Frederick R. Avis, Science Department, Saint Mark's School, Shrewsbury. (11th and 12th grades)

Michigan

CENTRAL MICHIGAN UNIVERSITY; *Chemistry, Physics, Mathematics* (*includes research*); 6 weeks beginning June 19; Malcolm H. Filson, Head, Departments of Chemistry and Physics, Mt. Pleasant. (11th and 12th grades)

THE UNIVERSITY OF MICHIGAN (at Grand Rapids); *Chemistry, Mathematics, Physics;* 6 weeks beginning June 19; Leigh C. Anderson, Chairman, Department of Chemistry, Ann Arbor. (Chiefly commuting—10th, 11th, and 12th grades)

MICHIGAN STATE UNIVERSITY; *Biology, Chemistry, Mathematics, Physics* (*in-*

cludes research); 6 weeks beginning June 19; M. Isobel Blyth, Department of Mathematics, East Lansing. (11th grade)

NORTHERN MICHIGAN COLLEGE; *Physical Sciences, Mathematics;* 4 weeks beginning July 31; Henry S. Heimonen, Department of Geography and Earth Sciences, Marquette. (11th grade)

WESTERN MICHIGAN UNIVERSITY; *Chemistry, Mathematics, Physics;* 6 weeks beginning June 19; George G. Mallinson, Dean, School of Graduate Studies, Kalamazoo. (11th grade)

Minnesota

AUGSBURG COLLEGE; *Chemistry;* 6 weeks beginning June 19; Courtland L. Agre, Chairman, Department of Chemistry, Minneapolis. (Commuting students only—10th and 11th grades)

SAINT CLOUD STATE COLLEGE; *Biology, Chemistry, Geology, Mathematics, Physics;* 4 weeks beginning June 12; Philip Youngner, Chairman, Department of Physics, Saint Cloud. (11th grade)

SAINT OLAF COLLEGE; *Biology, Mathematics, Physics;* 8 weeks beginning June 12; Thomas D. Rossing, Department of Physics, Northfield. (11th and 12th grades)

Mississippi

JACKSON STATE COLLEGE; *Mathematics;* 6 weeks beginning July 3; Benjamin H. McLemore, Head, Department of Mathematics, Jackson. (12th grade)

MISSISIPPI STATE UNIVERSITY; *Multiple Sciences;* 4 weeks beginning July 24; Clyde Q. Sheely, Department of Chemistry, State College. (11th grade)

Missouri

UNIVERSITY OF MISSOURI, SCHOOL OF MINES AND METALLURGY; *Engineering;* 7 weeks beginning June 11; Charles R. Remington, Jr., Department of Mechanical Engineering, Rolla. (Boys only—11th grade)

SAINT LOUIS UNIVERSITY; *Mathematics;* 4 weeks beginning June 26; John J. Andrews, Department of Mathematics, Saint Louis. (Commuting students only—11th grade)

WASHINGTON UNIVERSITY; *Chemistry;* 6 weeks beginning June 19; Richard Sutherland, Department of Chemistry, Saint Louis. (Commuting students only—11th grade)

WASHINGTON UNIVERSITY; *Biology;* 5 weeks beginning June 19; John Crenshaw, Department of Biology, Southern Illinois University, Carbondale, Illinois. (Commuting students only)

Montana

MONTANA STATE COLLEGE: *Geology;* 10 weeks beginning June 13; Charles C. Bradley, Dean, Division of Letters and Science, Bozeman. (Boys only—11th and 12th grades)

New Hampshire

KEENE TEACHERS COLLEGE at St. Paul's School, Concord; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning June 24, R. Philip Hugny, St. Paul's School, Concord. (10th, 11th, and 12th grades)

New Jersey

NEWARK COLLEGE OF ENGINEERING; *Biology, Chemistry, Mathematics, Physics;* 5 weeks beginning July 5; Joseph M. Fitzgerald, Department of Chemistry, Newark. (Commuting students only—10th, 11th, and 12th grades)

New Mexico

NEW MEXICO STATE UNIVERSITY; *Mathematics;* 6 weeks beginning June 26; E. L. Cleveland, Department of Physics, University Park. (Grades 11 and 12)

New York

American Museum—Hayden Planetarium; *Astronomy and Space Science;* 4 weeks beginning July 10; Franklyn M. Branley, Associate Astronomer, 81st Street and Central Park West, New York. (Commuting students only—9th, 10, 11th, and 12th grades)

University of Buffalo; *Biology, Chemistry, Physics* (*research*); 8 weeks beginning July 1; Robert Guthrie, Department of Pediatrics, School of Medicine, Buffalo. (10th, 11th, and 12th grades)

The City College; *Chemistry, Mathematics, Physics;* 6 weeks beginning July 3; Chester B. Kremer, Department of Chemistry, 139th and Convent Avenue, New York. (Commuting students only—10th, 11th, and 12th grades)

Colgate University; *Biology, Chemistry, Geology* (*research*); 6 weeks beginning June 26; Robert E. Todd, Department of Zoology, Hamilton. (Commuting students only—11th and 12th grades)

Cooper Union for the Advancement of Science and Art; *Multiple Sciences;* 6 weeks beginning July 3; Edward M. Griswold, Department of Mechanical Engineering, New York. (Commuting students only—11th and 12th grades)

Cornell University; *Biology, Chemistry, Geology, Physics* (*includes research*); 11 weeks beginning June 12; Philip G. Johnson, Department of Science Education, Ithaca

Cornell University; *Biology, Chemistry, Mathematics, Physics;* 6½ weeks beginning June 28; Thomas R. Nielsen, Department of Agronomy, Ithaca. (11th and 12th grades)

Hunter College; *Biology;* 6 weeks beginning June 30; Melvin S. Schwartz, Department of Physiology, New York. (10th and 11th grades)

Hunter College; *Geology;* 5 weeks beginning July 3; Henry D. Thompson, Department of Geology, New York. (Commuting students only—11th and 12th grades)

Manhattan College; *Physics, Mathematics;* 6 weeks beginning June 29; C. Leonard O'Connor, Department of Physics, New York. (Commuting students only—11th grade)

New York University; *Biological Sciences* (*research*); 6 weeks beginning June 19; Harry A. Charipper, Head, Department of Biology, Washington Square, New York. (Commuting students only—11th and 12th grades)

Polytechnic Institute of Brooklyn; *Chemistry* (*research*); 9 weeks beginning June 26; R. F. Riley, Department of Chemistry, Brooklyn. (Commuting students only—10th, 11th, and 12th grades)

Pratt Institute; *Chemistry, Mathematics, Physics;* 6 weeks beginning June 29; David Vitrogan, Department of Electrical Engineering, Brooklyn. (11th grade)

Roswell Park Memorial Institute; *Multiple Sciences;* 3 weeks beginning July 1; Edwin A. Mirand, Associate Research Scientist, Buffalo. (10th, 11th, and 12th grades)

Saint John's University; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning July 7; William H. Pasfield, Department of Chemistry, Jamaica. (Commuting students only—10th and 11th grades)

State University of New York—College of Education at Geneseo; *Biological Sciences;* 6 weeks beginning July 5; Edward F. Pierce, Department of Science, Geneseo. (Commuting students only—11th and 12th grades)

Syracuse University; *Biology;* 6½ weeks beginning June 28; Alfred T. Collette, Department of Bacteriology and Botany, Syracuse. (10th, 11th and 12th grades)

Waldemar Medical Research Foundation; *Biology* (*includes research*); 8 weeks beginning July 5; Norman Molomut, Director, Port Washington. (Commuting students only)

Yeshiva University; *Bio-medical sciences* (*research*); 8 weeks beginning July 5; M. D. Tendler, Department of Biology, New York. (Commuting students only—11th and 12th grades)

North Carolina

AGRICULTURAL AND TECHNICAL COLLEGE OF NORTH CAROLINA; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning June 11; Booker T. White, Department of Chemistry, Greensboro. (11th and 12th grades)

APPALACHIAN STATE TEACHERS COLLEGE; *Physical Sciences, Biology;* 5 weeks beginning July 17; F. Ray Derrick, Head, Department of Biology, Boone. (10th and 11th grades)

BENNETT COLLEGE; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning June 19; J. Henry Sayles, Chairman, Division of Sciences, Greensboro. (10th, 11th, and 12th grades)

LIVINGSTONE COLLEGE; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning June 12; Victor J. Tulane, Dean, College of Liberal Arts, Salisbury. (12th grade)

NORTH CAROLINA COLLEGE AT DURHAM; *Biology, Chemistry, Mathematics;* 6 weeks beginning June 11; James S. Lee, Chairman, Department of Biology, Durham. (11th and 12th grades)

NORTH CAROLINA STATE COLLEGE; *Biology, Chemistry, Mathematics;* 6 weeks beginning June 7; Willis A. Reid, Department of Chemistry, Raleigh. (11th and 12th grades)

UNIVERSITY OF NORTH CAROLINA; *Biology, Chemistry, Mathematics;* 6 weeks beginning June 12; Samuel B. Knight, Department of Chemistry, Chapel Hill (Boys only—11th and 12th grades)

WOMAN'S COLLEGE OF THE UNIVERSITY OF NORTH CAROLINA; *Chemistry, Mathematics;* 4 weeks beginning June 7; Hollis J. Rogers, Department of Biology, Greensboro. (Girls only—11th grade)

North Dakota

NORTH DAKOTA STATE UNIVERSITY OF AGRICULTURE AND APPLIED SCIENCE; *Biology, Chemistry, Mathematics, Physics;* 8 weeks beginning June 12; H. G. Heggeness, School of Chemical Technology, Fargo. (11th and 12 grades)

UNIVERSITY OF NORTH DAKOTA; *Multiple Sciences (includes research);* 6 weeks beginning June 19; Paul B. Kannowski, Department of Biology, Grand Forks. (10th and 11th grades)

Ohio

BOWLING GREEN STATE UNIVERSITY; *Chemistry;* 5 weeks beginning June 12; W. H. Hall, Department of Chemistry, Bowling Green. (10th, 11th and 12th grades)

CASE INSTITUTE OF TECHNOLOGY; *Mathematics;* 6 weeks beginning June 19; L. J. Green, Department of Mathematics, Cleveland. (Commuting students only—11th grade)

DENISON UNIVERSITY; *Biology (includes research);* 8 weeks beginning June 18; Robert W. Alrutz, Department of Biology, Granville. (11th and 12th grades)

HIRAM COLLEGE; *Chemistry;* 5 weeks beginning June 12; Edward B. Rosser, Department of Chemistry, Hiram. (10th and 11th grades)

HIRAM COLLEGE; *Physics;* 5 weeks beginning July 17; Edward B. Rosser, Department of Chemistry, Hiram. (10th and 11th grades)

KENYON COLLEGE; *Mathematics;* 4 weeks beginning June 25; Daniel T. Finkbeiner, Department of Mathematics, Gambier. (9th, 10th, and 11th grades)

OHIO STATE UNIVERSITY; *Biological Sciences (includes research);* 4 weeks beginning June 19; T. Scott Sutton, College of Agriculture and Home Economics, Columbus. (11th grade)

OHIO STATE UNIVERSITY; *Mathematics (includes research);* two sessions beginning June 19, 10 weeks and 5 weeks; Paul T. Yarrington, College of Engineering, Columbus. (Boys only—11th and 12th grades)

OHIO UNIVERSITY; *Biology, Chemistry, Mathematics, Physics (includes research);* 5 weeks beginning July 23; James T. Shipman, Department of Physics, Athens. (11th and 12th grades)

Oklahoma

OKLAHOMA STATE UNIVERSITY; *Multiple Sciences;* two 3-week sessions beginning June 12 and July 10; L. F. Sheerar, Department of Chemical Engineering, Stillwater. (11th grade)

SOUTHEASTERN STATE COLLEGE; *Mathematics;* 5 weeks beginning June 12; Leslie A. Dwight, Head, Department of Mathematics, Durant. (11th grade)

UNIVERSITY OF TULSA; *Physics, Mathematics;* 6 weeks beginning June 5; C. D. Thomas, Department of Physics, Tulsa. (12th grade)

Oregon

OREGON STATE COLLEGE; *Mathematics;* 7 weeks beginning June 26; R. E. Gaskell, Department of Mathematics, Corvallis. (Boys only—10th and 11th grades)

PORTLAND STATE COLLEGE; *Mathematics;* 10 weeks beginning June 12; Robert W. Rempfer, Department of Mathematics, Portland. (Commuting students only—10th and 11th grades)

Pennsylvania

BUCKNELL UNIVERSITY; *Biology, Chemistry;* 6 weeks beginning June 19; Lester Kieft, Department of Chemistry, Lewisburg. (Boys only—11th grade)

CARNEGIE INSTITUTE OF TECHNOLOGY; *Electrical Engineering;* 9 weeks beginning June 26; E. M. Williams, Head, Department of Electrical Engineering, Pittsburgh. (11th and 12th grades)

GENEVA COLLEGE; *Chemistry, Mathematics* (*includes research*); 9 weeks beginning June 13; Roy M. Adams, Chairman, Department of Chemistry, Beaver Falls.

LA SALLE COLLEGE; *Biology, Chemistry;* 8 weeks beginning June 26; John S. Penny, Chairman, Department of Biology, Philadelphia. (Commuting boys only—10th and 11th grades)

LEHIGH UNIVERSITY; *Mathematics* (*research*); 6 weeks beginning June 19; Albert Wilansky, Department of Mathematics, Bethlehem. (Commuting students only—11th and 12th grades)

UNIVERSITY OF PITTSBURGH at North Hills High School, Pittsburgh; *Biology, Biochemistry* (*research*); 12 weeks beginning June 19; John R. Jablonski, Research Associate, Addison H. Gibson Laboratory, School of Medicine, Pittsburgh. (Commuting students only—10th, 11th, and 12th grades)

TEMPLE UNIVERSITY; *Mathematics;* 6 weeks beginning June 26; Walter S. Lawton, Chairman, Mathematics Department, Philadelphia. (Commuting students only)

Rhode Island

BROWN UNIVERSITY; *Biology, Chemistry, Mathematics, Physics* (*includes research*); 6 weeks beginning June 26; Charles B. MacKay, Department of Education, Providence. (11th grade)

UNIVERSITY OF RHODE ISLAND; *Biological Sciences* (*research*); 4 weeks beginning July 10; William H. Wiley, Dean, College of Agriculture, Kingston. (Boys only—10th, 11th, and 12th grades)

South Carolina

SOUTH CAROLINA STATE COLLEGE; *Mathematics, Biology, Chemistry;* 6 weeks beginning June 19; George W. Hunter, Head, Department of Natural Sciences, Orangeburg. (11th and 12th grades)

WOFFORD COLLEGE; *Biology, Chemistry, Mathematics, Physics* (*includes research*); 7 weeks beginning July 20; James C. Loftin, Chairman, Department of Chemistry, Spartanburg. (Boys only—11th grade)

South Dakota

SOUTH DAKOTA STATE COLLEGE; *Chemistry, Mathematics;* 6 weeks beginning June 13; Stanley Sundet, Head, Department of Education, Brookings. (11th and 12th grades)

STATE UNIVERSITY OF SOUTH DAKOTA; *Mathematics (research)*; 6 weeks beginning June 19; Wayne W. Gutzman, Department of Mathematics. Vermillion. (12th grade)

Tennessee

LEMOYNE COLLEGE; *Biology, Chemistry, Mathematics;* 6 weeks beginning June 12; W. W. Gibson, Chairman, Division of Natural Sciences, Memphis. (Commuting students only—11th and 12th grades)

SOUTHWESTERN AT MEMPHIS; *Chemistry (research)*; 6 weeks beginning June 12; Raymond T. Vaughn, Department of Chemistry, Memphis. (Commuting students only—11th and 12th grades)

UNIVERSITY OF TENNESSEE: *Chemistry, Physics (includes research)*; 6 weeks beginning June 12; J. H. Wood, Department of Chemistry, Knoxville. (Boys only—10th grade)

Texas

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS; *Geology;* 6 weeks beginning July 17; Fred E. Smith, Department of Geology, College Station. (Boys only—10th and 11th grades)

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS; *Biological Sciences (research)*; 6 weeks beginning July 17; John J. Sperry, Department of Biology, College Station. (Boys only—10th, 11th, and 12th grades)

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS; *Mathematics, Astronomy;* 6 weeks beginning June 19; Jack T. Kent, Department of Mathematics, College Station. (Boys only—11th grade)

EAST TEXAS STATE COLLEGE; *Mathematics;* 6 weeks beginning July 17; C. B. Wright, Department of Mathematics, Commerce. (11th and 12th grades)

UNIVERSITY OF HOUSTON; *Multiple Sciences (includes research)*; 6 weeks beginning July 17; John C. Allred, College of Arts and Sciences, Houston. (10th grade)

PAN AMERICAN COLLEGE; *Astro-sciences;* 6 weeks beginning June 5; Paul R. Engle, Director, Observatory and Astro-Science Center, Edinburg. (10th, 11th, and 12th grades)

PRAIRIE VIEW AGRICULTURAL AND MECHANICAL COLLEGE; *Chemistry;* 6 weeks beginning June 12; E. E. O'Banion, Head, Department of Natural Sciences, Prairie View. (11th and 12th grades)

PRAIRIE VIEW AGRICULTURAL AND MECHANICAL COLLEGE; *Mathematics;* 6 weeks beginning June 12; Israel E. Glover, Head, Department of Mathematics, Prairie View. (11th and 12th grades)

PRAIRIE VIEW AGRICULTURAL AND MECHANICAL COLLEGE; *Biology;* 6 weeks beginning June 12; Charles H. Nicholas, Chairman, Department of Biology, Prairie View. (10th, 11th, and 12th grades)

SOUTHERN METHODIST UNIVERSITY; *Mathematics;* 5 weeks beginning June 11; Frank J. Palas. Department of Mathematics, Dallas. (11th grade)

STEPHEN F. AUSTIN STATE COLLEGE; *Biology;* 6 weeks beginning July 16; Edwin L. Miller, Head, Department of Biology, Nacogdoches. (10th and 11th grades)

TEXAS WOMAN'S UNIVERSITY; *Biology, Chemistry, Mathematics;* 8 weeks beginning June 12; Robert W. Higgins, Department of Chemistry, Denton. (Girls only—11th grade)

TEXAS TECHNOLOGICAL COLLEGE: *Physics;* 5 weeks beginning June 5; J. W. Day, Department of Physics, Lubbock. (10th, 11th, and 12th grades)

UNIVERSITY OF TEXAS—M. D. Anderson Hospital and Tumor Institute; *Biological Sciences (includes research)*; 8 weeks beginning June 12; Murray M. Copeland, Assistant Director for Education, Houston. (11th and 12th grades)

UNIVERSITY OF TEXAS; *Mathematics;* 6 weeks beginning June 12; H. J. Ettlinger, Department of Mathematics, Austin. (10th and 11th grades)

UNIVERSITY OF TEXAS; *Chemistry;* 6 weeks beginning June 12; R. L. Augustine, Department of Chemistry, Austin. (11th grade)

WILEY COLLEGE; *Biology;* 6 weeks beginning June 12; N. H. Anderson, Divison of Natural Sciences and Mathematics, Marshall. (11th and 12th grades)

Utah

UNIVERSITY OF UTAH; *Geology;* 6 weeks beginning July 24; William Lee Stokes, Head, Department of Geology, Salt Lake City. (Boys only—11th and 12th grades)

UNIVERSITY OF UTAH; *Mathematics, Physics;* 4 weeks beginning June 5; E. Allan Davis, Department of Mathematics, Salt Lake City. (Commuting students only—10th and 11th grades)

Virginia

EMORY AND HENRY COLLEGE; *Multiple Sciences;* 5 weeks beginning June 19; Marius Blesi, Department of English, Emory. (11th and 12th grades)

VIRGINIA STATE COLLEGE—NORFOLK DIVISION; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning June 19; Paul L. Brown, Head, Department of Biology, Norfolk. (10th, 11th, and 12th grades)

UNIVERSITY OF VIRGINIA (at Fairfax High School, Fairfax); *Chemistry (includes research);* 8 weeks beginning June 19; Bart van't Riet, Department of Chemistry, Charlottesville (Commuting students only—10th and 11th grades)

VIRGINIA UNION UNIVERSITY; *Biology;* 6 weeks beginning June 26; Walter O. Bradley, Director, Division of Natural Sciences and Mathematics, Richmond. (11th and 12th grades)

Washington

WHITWORTH COLLEGE; *Biology, Chemistry, Physics (includes research);* 6 weeks beginning June 19; William G. Wilson, Department of Physics, Spokane. (10th, 11th, and 12th grades)

West Virginia

WEST VIRGINIA UNIVERSITY; *Biology, Chemistry, Physics (includes research);* 4 weeks beginning June 5; O. J. Burger, Division of Agriculture. Morgantown. (Boys only—11th grade)

WEST VIRGINIA WESLEYAN COLLEGE; *Multiple Sciences;* 4 weeks beginning July 31; John C. Wright, Department of Chemistry, Buckhannon. (10th and 11th grades)

Puerto Rico

COLLEGE OF AGRICULTURE AND MECHANIC ARTS; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning June 5; Eddie Ortiz, Department of Physics, Mayaguez. (10th, 11th, and 12th grades)

INTER AMERICAN UNIVERSITY; *Multiple Sciences;* 7 weeks beginning May 29; Ismael Velez, Director, Division of Natural Sciences, San German.

UNIVERSITY OF PUERTO RICO; *Biology, Chemistry, Mathematics, Physics;* 6 weeks beginning May 22; Francisco Garriga, Division of Natural Sciences, Rio Piedras. (11th grade)

Supervision of Science and Mathematics*

James W. Busch

Supervisor of Science, Department of Public Instruction, Madison, Wisconsin

Up to three years ago, only four or five state departments of education had on their staff a person with special training and responsibility in the field of science education and even fewer had any such person in mathematics education. Today nearly every state has one or more persons so assigned. In general, this same situation also holds true with respect to personnel with similar responsibilities at the local district level. Where several years ago only the largest districts were likely to have a special supervisor in any academic area, today even some of our relatively small districts have been able to assign a qualified person at least some time for the task of coordinating or supervising science and/or mathematics.

There have no doubt been several reasons for this increase in emphasis on special supervisors in these subjects. One, of course, is the impact of the money provided by the National Defense Education Act for such supervisors at the state level. That this is true is demonstrated by the fact that nearly all of the science and mathematics supervisors employed at the state level since the enactment of the National Defense Education Act are paid out of N.D.E.A. funds. However, a more basic reason for the increase is the realization on the part of educators and the general public that an improved science and mathematics program in our public schools is essential if we are to meet the needs of our society and the individual in this society. Much of the increase can certainly be credited to this realization coupled with a recognition of the need for adequate, competent leadership if the necessary improvement is to be accomplished.

In the light of this growth in the number of supervisors we face the question, "What is the role of the supervisor in improving instruction in science and mathematics?" An examination of the literature reveals that the position of the supervisor has been a controversial issue in the past. Burton and Brueckner in their book *Supervision—A Social Process*, attribute much of this controversy to the historic development of supervision as an inspectorial function. That this attitude towards supervision still persists to some degree is evidenced by joking references to "snoopervision" or such statements as "He never interferes with my teaching," when commenting on a principal, as well as the fact that some people still refer to state supervisors as "state inspectors." Fortunately, however, we increasingly

* A summary of an address given at the 60th convention of the Central Association of Science and Mathematics Teachers in Detroit, Michigan on November 26, 1960.

are finding a new and more wholesome attitude toward supervision and the supervisor. This viewpoint places the supervisor in the role of leadership in cooperatively improving the learning situation. In recognition of this new role some systems are replacing the title of supervisor with the newer title of consultant. This may perhaps create a more desirable impression in the minds of some people. However, more important than the title, is the working relationship which exists between the supervisor and those with whom he works. For example, the development of a desirable working relationship in Wisconsin is illustrated by the fact that the major portion of the work of the state science supervisor is with schools that request his services in working together with them toward the improvement of their science programs. They are not for the most part looking for someone to do the job for them or tell them what to do. They are looking for leadership that has, by virtue of knowledge of both subject matter and methods and by virtue of the opportunity to see the over-all situation, including recent developments in the field, the ability to make specific contributions which will help them to develop the best possible program for improving science instruction in their own situation.

At this point it would be well to emphasize several prerequisites which must be met if the supervisor is going to be able to make an effective contribution to the improvement of instruction. First, the supervisor must have adequate time and an administrative organization which will permit the exertion of the leadership role that we have described. It is extremely easy for the supervisor to find himself involved in administrative details to the extent that he has not time to carry out his primary responsibility. Similarly, important as it may be to have someone in a school science department to perform such tasks as coordinating the ordering of supplies or acting as chairman at department meetings, such a person does not satisfy the need for a science supervisor as described here.

Another prerequisite for effective action is that the supervisor must be one who will be accepted and respected by those with whom he will work. This requires that he be a competent, well qualified teacher with a substantial amount of classroom experience, that he exhibit a real interest in the improvement of instruction in science by such means as his membership in professional and scientific organizations and by his own efforts in professional growth, and that he have the personal qualities which enable him to work well with others. Also, while he must be particularly qualified in his own subject field, it is most important that the supervisor have an insight into the total educational program and that he work well with general supervisors and others who have an over-all responsibility. Additions can be

made to this list of requirements and certain aspects can be expanded upon to fit particular situations.

Consider then the specific activities which the science supervisor will need to undertake to improve the learning situation. Here again it is difficult to lay out a complete blueprint for action as the specific circumstances of each situation will to a large degree determine the direction which the supervisors efforts must take. For example, while the state science supervisor, the science supervisor in a large system and their counterpart in a small system will all be working for the same goal, their methods must of necessity vary greatly. The state supervisor, both because of the nature of his position and because of the limited time which he will have to work with any single system, will in most cases work largely with and through local leadership. This does not mean that the state supervisor will not visit classes or meet with teachers. Indeed, the bulk of his time should probably be spent in such activities, but the extended work with individual teachers or with the detailed development of programs must of necessity rest with local leadership. Therefore, the state supervisor works most effectively in strengthening and encouraging the efforts of this local leadership. On the other hand the science supervisor for a local district will more often be in a position to work directly with individual teachers who need his help for an extended time and will certainly be the person who exerts continuing leadership in any activity undertaken at the local level for the improvement of instruction. Again, however, many differences will exist in specific activities undertaken in various local systems. This is certainly desirable when one considers that the needs or weaknesses are not likely to be same in every situation.

This then is probably a key to the effectiveness of any program. To the extent that any undertaking is based on a careful evaluation of the need in the local situation, to that extent will it be likely to contribute to real improvement in that situation. Furthermore it is important that a majority of the teachers involved are convinced that there is a real need before the program is likely to be successful. (It is probably asking too much to expect every teacher to be enthusiastic about any improvement activity.)

In spite of the variation between different systems, however, I believe that there are certain common problems. which most science supervisors will face. One of the most important of these needs is the development of a well articulated 12-grade science program. Such a program must not only provide adequate time for teaching science at every grade level in the elementary school as well as give adequate emphasis to science in the junior and senior high school, but must also insure that adequate emphasis is given to all areas of science,

particularly at the elementary school level. Also it is important to re-emphasize the necessity of planning this science program so that there is a sequential development of concepts from grade level to grade level. We simply do not have time to afford the luxury, or the ridiculous waste, of teaching exactly the same thing several times in the elementary schools, again in the junior high school and finally again at senior high school. For example, consider a clipping from the University of Wisconsin newspaper, "The Daily Cardinal," in which Dr. Suomi, one of the developers of instruments contained in our weather satellites, relates that when in seventh grade he was required to conduct an experiment in which iron filings were sprinkled on a piece of cardboard. With a magnet held under the cardboard, the bits of iron were made to cluster together and move back and forth with the motion of the magnet. "We did the same experiment in ninth and tenth grades and again in college physics class. I think I understood the principle involved by the time I got to college. We need to offer young people more challenging things than this," he said. The writer has even observed this same experiment done at the second grade level. Needless duplication such as this often exists where the science program is not well planned.

Now, what is the answer to this problem? Certainly no one teacher working at a particular level can correct this situation. Nor can even national committees working on a particular subject offer the answer. Here is where supervisory leadership is essential if the situation is to be improved. Furthermore, the administrative organization must be such that it will facilitate working toward the solution of such problems. The writer has visited some school systems where, for example, junior and senior high school teachers had no idea what was being taught at any level other than their own, never met together and, in fact, did not know one another even though the systems were relatively small. Certainly lack of communication such as this will never lead to well articulated programs.

Another problem area in which most science supervisors will need to exert leadership is that of the in-service growth of teachers. The specific needs may vary from situation to situation, but the problem of helping teachers to keep abreast of necessary new developments in a field as dynamic as science is a challenge everywhere. The needs of elementary teachers in many places is particularly critical. This is not surprising when one considers the meager preparation which many elementary teachers are receiving in science even in some of our supposedly best institutions. It does, however, necessitate leadership on the part of the science supervisor to provide help for these teachers. One means by which several Wisconsin communities have been able to provide such help is through locally conducted workshops for their

elementary teachers. In these workshops the elementary teachers are actually taught science and are given the opportunity to work with science equipment. Many teachers have received this help most enthusiastically. In addition to this approach, it will certainly be desirable for the supervisor to use such techniques as demonstration teaching and to confer with and advise individual teachers regarding special problems.

While I have particularly referred to the needs of elementary teachers here, an even more difficult problem is the science teacher who completed his undergraduate preparation 10 or 20 years ago and has not taken another course, attended a meeting of a society such as CASMT or probably has not even read anything professional since graduation. Fortunately, because of the impact of the National Science Foundation and other institutes which have been made available over the past few years, we probably have fewer of such teachers in science and mathematics today than we did several years ago, but nevertheless they are a problem.

In addition to the two major problems considered above to which science supervisors can make a contribution, one could add many more activities in which the science supervisor could profitably be engaged. One, for example, in which the writer has been able to contribute help to a number of schools is in the field of planning science laboratory facilities. It is really surprising, although it probably shouldn't be, how little knowledge many architects have of the laboratory space and furniture requirements for a good modern science program.

In conclusion, I would like to reemphasize that the supervisor is a leader in the improvement of the learning situation. Thus, the problems with which the science supervisor deals are those facing everyone concerned with science education. As I said at the beginning, we do find an increasing number of such supervisors today. However, I believe many more are needed, and as science teachers work together through organizations such as this, I think that we can help more people to realize the importance of providing this kind of leadership. This will help us to move forward cooperatively to meet the challenges which we all face.

Pacific Northwest glaciers are receding, the United States Geological Survey reported after completing 1960 measurements. At and below 6,000 feet, accumulation from snowfall has not matched the loss.

Measurements at 6,800 feet, however, indicate that accumulation exceeds loss from melt and "ablation," a geological term indicating the volume worn away by the glacier's descent over its rocky base.

Supervision of Science and Mathematics*

Haron J. Battle

Supervisor of Secondary Education, Gary Public Schools, Gary, Indiana

General Purpose of Supervision

Education in America is a rapidly growing enterprise, involving a large variety of services. Within the last few years the National Science Foundation and the National Defense Education Act have made significant contributions toward the growth of educational programs in science and mathematics through assistance in the training of teachers and the acquisition of improved instructional equipment and other aids. These and many other developments are leading to an increased need for supervision in education.

The supervisor is concerned primarily with improving the quality of instruction in the subject area or areas for which he is responsible. In this sense he is not basically different from other members of the school staff, for high quality instruction is the objective of the total educational program. I shall attempt, therefore, to identify and discuss some of the unique functions of the person who assumes the role of supervisor, with special emphasis on its application in the fields of science and mathematics.

The Role of the Supervisor

The image of the supervisor has undergone considerable change, from that of a person with authority to administer programs and people in accord with his judgment, to that of a leader and coordinator who works with programs and people in accord with the best ideas that may emerge from the group and within the current philosophy of the school system. This trend seems to be both necessary and desirable, for it allows maximum utilization of the best resources available in the planning and operation of programs. Through the interaction of the thinking of the new teachers coming in with ideas from universities; the experienced teachers with intimate understanding of the students, the subject, and effective methods of teaching; the supervisor with insights gained through studying and observing the program as a whole; and other staff members who tend to see science and mathematics in relation to various aspects of the total school program, developments in instruction are likely to be practical and progressive. In addition, cooperative action in planning and operating programs tends to facilitate communication among members of the staff with respect both to understanding and ac-

* Summary of an address for the 60th Annual Convention of the Central Association of Science and Mathematics Teachers, November 26, 1960, at the Statler Hilton Hotel, Detroit, Michigan.

cepting the ongoing developments. The person who is an active participant in planning a program is in a favorable position to be effective in implementing and evaluating it.

The supervisor works primarily with teachers. However, he is in close contact with principals, other supervisors, and personnel in many of the special services. He is expected to keep the superintendent informed of developments in the areas for which he is responsible and to interpret school policy as it may relate to items under consideration by the instructional staff.

In seeking to improve instruction, the supervisor is concerned specifically with helping organize and execute an ongoing program of curriculum development, assisting in the identification and acquisition of instructional aids, stimulating professional growth activities, facilitating the teaching-learning process, and sharing in the evaluation of programs and the examination and revision of goals and procedures.

The Gary Program as an Example

In discussing the functions of the science and mathematics supervisor, I shall refer repeatedly to the program in the Gary Public Schools, Gary, Indiana, primarily because I am familiar with what has occurred in Gary and this will serve as an example of one approach to the task of supervision. The plan of supervision in the Gary Public Schools has undergone several transformations. During the thirties there was a supervisor of mathematics and a supervisor of science, each responsible for elementary and secondary programs. In the forties there was a move toward the assignment of a general secondary supervisor and a general elementary supervisor. In addition, special supervisors for homemaking, music, speech and dramatics, physical education, and vocational education were retained. In the fifties the general supervisory staff was increased to provide for some degree of specialization.

Presently the supervisor of science and mathematics is also responsible for the supervision of guidance. His areas of responsibility, therefore, include 72 teachers of mathematics, 51 science teachers, and 29 counselors. However, there is now a full-time science teacher coordinator who is responsible for most of the supervisory work in science. Through the program sponsored by the National Science Foundation and Michigan State University, this year he is acting also as a locally-sponsored visiting science teacher, serving only the Gary Public Schools.

Curriculum Development

A major task of the supervisor is that of providing leadership in

curriculum development. He is expected to lead in forming an organizational structure which includes all members of the staff concerned with instruction and in promoting the work that is done within the structure. In the process of developing the curriculum the staff should have information concerning the needs of students, the demands for education suggested by trends in society, findings from research and experience locally and nationally with respect to science and mathematics education and the learning process, the current philosophy for the school system, and available teaching aids. The supervisor assumes leadership in acquiring materials and arranging activities that will aid in keeping the staff informed in these areas.

Four years ago in Gary we formed an organizational structure for the purpose of reviewing the curriculum and developing a guide for each subject area in the secondary schools. In the structure, the basic group for each department was a city committee that included the supervisor and a representative for each of the nine secondary schools. These representatives served as members of the city committee and as leaders on their respective school committees to maintain two-way communication with the entire staff.

Recommendations from the city committee were reviewed by a general planning council which included all of the supervisors, two principals, and a teacher representative-at-large from each school. The council reviewed the recommendations from departments with respect to their effect on the total school program. The council could make its own recommendations, but it could not veto any recommendations made by the departments.

The combined set of recommendations from the committees and the council were submitted to the Assistant Superintendent who, along with the Superintendent, reviewed them in meetings of secondary principals and supervisors. The resulting recommendations were submitted to the Gary Board of School Trustees and then to the State Department of Public Instruction for approval.

From this procedure there emerged an official outline for each of the 145 courses authorized to be offered in the secondary schools. For each course the outline shows the major areas, emphases or outcomes, typical activities, and aids for instruction.

The courses developed under this procedure were designed to provide for differences among students with respect to abilities, interests, and goals. In science and mathematics three sequences of courses are included in the curriculum. These may be termed general, regular, and accelerated sequences. The accelerated sequence permits a student to complete the regular courses by the end of the junior year, making it possible to use the senior year for advanced study.

After working on this project rather intensively for about two years, we spent the next two years implementing and observing the program. This year we have formed a somewhat different structure to continue the ongoing program of curriculum development. For each department, the new structure includes the general staff, which meets twice during the year mainly for information and stimulation; school committees which function as the basic units in the structure; a city committee, including one representative from each of the nine secondary schools, which has half-day sessions two or three times during the year to review the program and make recommendations regarding policy, materials, and special projects; and work committees that meet on Saturdays or during the summer to perform tasks recommended by the city committee and approved by the Superintendent and Board of School Trustees.

As an example of the plan in action, presently the city science committee is recommending that a small work committee be authorized to outline a third-semester course in biology and the city mathematics committee is asking for a similar committee to prepare supplementary practice materials.

Identification and Acquisition of Instructional Aids

Closely related to the supervisor's role as a leader in curriculum development is his responsibility with respect to instructional equipment and materials. His primary function in this area is to assume leadership in identifying the teaching aids that are likely to be most effective in strengthening instruction. These include textbooks, supplementary materials, laboratory equipment and supplies, audio-visual aids, and new or remodeled housing facilities. In performing this task, as with others, the supervisor works through a structure designed to make maximum use of contributions from the staff.

As an example of operation in this area of work, we might consider the selection of textbooks. In Indiana we operate on five-year adoptions. For each approved course the state makes multiple adoptions from which local school systems may choose. Last year we adopted mathematics books; this year we will adopt books for science. To accomplish this task the supervisor works with the city committee, whose members in turn work with the respective school committees. A sample copy of each of the textbooks adopted by the state is acquired for each member of the city committee. This provides a complete set of state adopted books for examination in each school. With recommendations obtained in the schools and in compliance with previously established criteria, in two or three half-day sessions, the city committee makes the selections for the school system. Supplementary materials, which may or may not be on the state list, also

are selected through this procedure.

All of the recommended materials are listed by grade and subject in a requisition guide which supplies all of the information needed for placing orders. With this guide, for each item, the teacher has to fill in only the quantity on hand and the quantity requested. The remainder of the clerical process can be completed through the office staff. For supplementary and experimental materials the guide is revised annually. Before this system was introduced the supervisor spent much time during requisition periods on questions from principals concerning a variety of materials requested for purchase. Now only an occasional recently published or discovered item may require this kind of special attention.

Participation in the National Defense Education Act, Title III

The supervisor of science and mathematics, more than any other person in a local school system, is responsible for leadership in utilizing the National Defense Education Act, Title III, for strengthening instruction. With this function, in addition to the instructional staff, he has to work with the finance department, which includes the budget director, accountant, purchasing agent, and the director of the department. In view of the large number of people involved in the planning and development of these projects, it seems very desirable to establish through committee action a well-defined set of policies and procedures which are approved by the superintendent and understood and endorsed by all participants.

Our procedures in Gary have passed through several stages. Now we have three categories of projects: (1) library materials, (2) classroom supplementary and reference books, and (3) budget items which may include equipment and facilities. All projects are developed for the school system, although items are grouped by schools. For each project, in the initial stage of development, the supervisor obtains from the finance department a local project number to facilitate IBM accounting.

The city committee, in cooperation with school committees and librarians, recommends materials to be acquired for the libraries and the classrooms. Through the leadership of the supervisor, the requests from schools are assembled into city Title III projects, one for library books, and another for supplementary classroom materials. Upon approval of a project by the state committee, through arrangement with the local budget director, the respective school accounts are reimbursed in the amount of one-half the cost of the project.

It seems that the most successful plan for projects including equipment or minor remodeling of facilities is to work through the regular

procedure for developing the annual budget for the school system. The supervisor assists principals and committees in identifying needs. Requests are submitted to the respective budget committees, who are encouraged to be liberal in approving the items in view of the possibility for reimbursement. At one step in the process, the supervisor serves as chairman of a committee of administrators that makes a city-wide ranking of all items requested by schools. To the extent that the provisions are understood and utilized, all of these procedures tend to have schools acquire about twice the quantity of teaching aids for Title III subjects as would be acquired without the Act.

Stimulating Professional Growth

The quality of education in a classroom depends primarily on the competence of the teacher. Although preferably not directly involved in the administrative process of employing and evaluating personnel, the supervisor, nevertheless, has a definite opportunity and responsibility to aid in recruiting, orienting, and stimulating the professional growth of teachers. Supervisory activities in this area may include establishing contacts with colleges and universities, interviewing candidates for teaching assignments, conducting orientation activities for new teachers, visiting classes and conferring with teachers, planning or promoting professional growth activities within the school system, and stimulating participation in institutes and other professional programs. Of these activities, classroom visitation is considered most significant. In this activity the supervisor has an opportunity to observe instruction in operation, act as a second teacher in working with students during supervised study, discuss problems of concern to the teacher, and share any ideas that might seem to be helpful.

Facilitating the Teaching-Learning Process

In addition to the activities that have been described, the supervisor may discover other ways to facilitate the teaching-learning process. For example, he may have an opportunity to interpret the curriculum to parents, help accomplish a reduction of teaching loads, assist in the utilization of community resources, work with community representatives in conducting activities for gifted students, or help with problems of grouping students.

Evaluation of the Curriculum

The effectiveness of the curriculum should be assessed with devices designed to indicate the amount of change produced in students in the direction of objectives as defined by the staff. The super-

visor works with research personnel and the instructional staff in defining objectives and identifying or developing appropriate devices for assessing learning. Plans for experimental projects should include adequate provision for pre- and post-testing. In general, any major change in the instructional program should be based on significant evidence in support of the proposed change.

SUMMARY

The supervisor is concerned with improving the quality of instruction through work with the staff, teaching aids, facilities, community resources, and other available means. The effectiveness of his work depends largely on the degree to which he can keep informed on developments and resources in his subject areas, establish and maintain good rapport with the staff, facilitate professional growth, and lead in the development and operation of an organizational plan that provides for the participation of the staff in making constructive decisions related to instruction.

PHYSICISTS DEVELOP LOW TEMPERATURE COMPONENT

A simply constructed device for use in low-temperature electronic circuits has been developed.

The new device, called a tunneltron, may extend the range of low-temperature, or cryogenic, instruments to include low-noise amplifiers, high-frequency oscillators and computer components.

Physicists working at Arthur D. Little, Inc., Cambridge, Mass., observed an unexpected "switch-back action" or negative resistance region when current was passed through a metal-dielectric-metal sandwich at temperatures approaching absolute zero, or 459.7 degrees below zero Fahrenheit. The resistance effect stems from the ability of electrons to pierce or "tunnel" through extremely thin layers, about a millionth of an inch thick, of material normally considered to be insulating.

The tunneltron is based on the principle of using a changing magnetic field to control the tendency of certain metals to lose electrical resistance at low temperatures.

TOOLS OF ANCIENT MAN TELLS HIS EVOLUTION

The tools early man left behind him tell scientists more about man's evolution than do his bones.

The most important developments in man's evolution can be found from his cultural remains and by ethnological observations. The brain, not the bones, is the most important factor in human evolution.

The broad outlines of the evolution of man's skeleton are well known. They fit with what is known of the evolution of apes. However, the evolution of the important soft tissues of humans is less well known, and that of the central nervous system and the brain, except roughly for size and configuration, is not known. A long-dead skull does not reveal much about the brain once housed in it.

Scientific Research—A Hobby?

Morris Goran

Roosevelt University, Chicago, Illinois

In 1959, a retired professor of chemistry at the University of Chicago received several of the highest awards of the American Chemical Society in recognition of his research in the chemistry of boron. Unfortunately, this chemist's work at the University of Chicago was largely concerned with teaching and administration; whereas his research with boron was largely a spare-time activity. This hobby has paid tremendous dividends in terms of rocket fuels.

Since pre-historic times, scientific research has too often been a hobby. Yet, this hobby has aided man more than any other single one. The greatest inventions of all times the wheel, the control of fire, the domestication of animals, agriculture—are considered by some to be a result of spare-time activity. It is highly unlikely that concentrated, day-by-day effort produced these marvels. Likewise, the tremendous achievements of Aristotle, that influenced mankind 2000 years later, were carried on with other activities, namely, teaching and administration.

The experimental physiologist Galen is considered a top scientist of the Roman world, yet his tremendous writings and researches were not a main activity. They were produced along with his work as a teacher and physician. The pioneers of modern science—Copernicus, Galileo, and Kepler—spent many more hours in work other than research. An exception was Brahe, who was supported by the Danish monarch for the purpose of astronomical research and had a corps of assistants along with an island observatory.

Isaac Newton had light teaching duties at Cambridge University —about an hour a day for 12 weeks of the year—and could have been a full-time scientific researcher. But he was more interested in theology, alchemy, and dabbling in politics. Newton's contemporary, Robert Hooks, for a time held a full-time position as an experimenter for the Royal Society. His *Micrographia* attests that this genius was responsible for many discoveries.

Even during the eighteenth and nineteenth centuries, when science grew in importance and the values of scientific research became more evident, it was still often a spare-time activity. Vast numbers of great achievements in any science came from hobbies.

The first half of the twentieth century fails to elicit a major shift in a perspective for time devoted to scientific research. College teachers seldom had time for the activity. University professors had to find time for it if they were to achieve promotion and other emoluments of the professoriat.

The type of research institution described by seventeenth-century Francis Bacon in his *New Atlantis*, where men and women do nothing but scientific research are few in number. Barely twenty years ago, only a few in the United States had the aduacity to advocate national laboratories such as Argonne and Brookhaven.

Since the record of history shows beyond question that scientific research is productive and economical, it is amazing to find the lag in setting up institutes to understand and conquer man's age-old problems of hunger, cold, communication, transportation, and disease.

MATHEMATICS APPLIED TO A COMMON CUSTODIAL PROBLEM

Cecil B. Read
Mathematics Editor
and Donald F. Cowgill
University of Wichita, Wichita, Kansas

The formula reproduced below was discovered by the mathematics editor, written on the blackboard in a classroom. Some elementary sleuthing revealed that the individual responsible was an undergraduate student (Mr. Cowgill) who was employed as a part time student assistant on the custodial staff. His duties were largely cleaning classrooms. The editor felt this was worth sharing with our readers, if for no other reason than to show that students still enjoy poking fun at a subject they enjoy.

Determination of the Angle at Which to Shake a Mop

Let θ be the angle at which to shake the mop, then

$$\tan\theta = \sum_{n=0}^{\infty} x^{n+1}\frac{(n+2-z)}{n!} + \int_0^{\phi}\int_0^{z}\frac{x\log\tan\phi\,dx\,d\phi}{\rho}\left[\frac{\text{covers}(\sigma-\phi)+y^{\sigma\pi}}{(\sin\sigma\cos\phi)\,|y^{8\sigma}|}\right]$$

$$+\frac{d}{dl}\,(l_0-e^{n+\sigma})$$

where

n = number of shakes
x = length of mop handle
z = distance between hands, in cm.
θ = angle between mop head and handle
y = width of mop head, in cm.
t = time allowed by boss
l_0 = temperature in degrees Kelvin
ρ = density of air ($\rho = 1$ in a vacuum) as found in Table VI, Appendix III: Higher Developments in Mopflopping
σ = constant pertaining to oiliness of mop, found in Table DIVX, p. 2609, Mop Jockey's Guide

Problem Department

Conducted by **Margaret F. Willerding**

San Diego College, San Diego, Calif.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problem should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the Department desires to serve her readers by making it interesting and helpful to them. Address suggestions and problems to Margaret F. Willerding, San Diego State College, San Diego, Calif.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solution should observe the following instructions.

1. Solutions should be in typed form, double spaced.

2. Drawings in India ink should be on a separate page from the solution.

3. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

4. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

2648, 2743, 2751, 2753, *Felix John, Philadelphia, Pa.*

2753, 2754, *H. R. Leifer, Pittsburgh, Pa.*

2755. *Proposed by Brother Felix John, Philadelphia, Pa.*

Prove that the expression $x^5-bx^3+cx^2+dx-e$ will be the product of a complete square and a complete cube if

$$12b/5=9d/b=5e/c=d^3/c^3.$$

Solution by W. R. Talbot, Jefferson City, Mo.

Let the given polynomial be $(x-a)^2(x-h)^3$. Equating coefficients gives

$$2a+3h=0, \qquad a^2+6ah+3h^2=-b, \qquad -h(3a^2+6ah+h^2)=c,$$
$$ah^2(3a+2h)=d, \qquad a^2h^3=e.$$

Substituting $h=-2a/3$ into the last four equations gives

$$b=5a^2/3, \qquad c=-10a^3/27 \qquad d=20a^4/27, \qquad e=-8a^5/27.$$

It is readily shown then that

$$4a^2=12b/5=9d/b=+5e/c=d^3/c^3.$$

Solutions were also offered by H. R. Leifer, Pittsburgh, Pa., H. C. Torreyson, Prospect Heights, Ill.; Herbert Wolf, Chicago, Ill.; and the proposer.

2756. *Proposed by Lee Mitchell, Glencoe, Ill.*

Find the smallest natural number which has the froms $5n+1$, $7n+3$, $11n+5$, and $13n+7$.

Solution by H. R. Leifer, Pittsburgh, Pa.

Let N be the number sought and let N' be a natural number of the form $5n+1$

and $7n+3$, then

$$N'=5a+1=7b+3, \qquad a, b \text{ integers},$$
$$5a+1=7b+3,$$
$$5a-7b=2, \text{ and}$$
$$a=6-7r,\ b=4-5r, \ (r \text{ an integer}), \text{ and}$$
$$N'=31-35r.$$

Let N'' be a natural number of the form $11n+5$ and $13n+7$, then

$$N''=11c+5=13d+7 \qquad c, d \text{ integers},$$
$$11c+5=13d+7,$$
$$11c-13d=2, \text{ and}$$
$$c=12-13s,\ d=10-11s, \ (s \text{ an integer}), \text{ and}$$
$$N''=137-143s.$$
$$N=31-35r=137-143s,$$
$$31-35r=137-143s,$$
$$143s-35r=106, \text{ and}$$
$$r=5194-143t,\ s=1272-35t, \ (t \text{ an integer}), \text{ and}$$
$$N=5005t-181759.$$

For N to be the smallest natural number of the form sought, t must be 37 and $N=185185-181759=3426$.

Solutions were also offered by Robert Gaskell, Corvallis, Ore.; Felix John, Philadelphia, Pa.; J. H. Means, Austin, Texas; W. R. Talbot, Jefferson City, Mo.; H. C. Torreyson, Prospect Heights, Ill.; Dale Woods, Kirksville, Mo.; and the porposer.

2757. *No solution has been offered.*

2758. *Taken from "Mathematical Pie"*

Twelve tickets numbered from 1 to 12 were folded and shaken up in a box. They were then drawn out in pairs and the total of the two numbers for each pair were called out. If the totals were 4, 6, 13, 14, 20, and 21 what were the numbers of each pair?

Solution by Dale Woods, Kirksville, Mo.

Since

$$4=1+3,\ 6=1+5=2+4,\ 13=1+12=2+11=3+10=4+9=5+8=6+7,$$
$$14=2+12=3+11=4+10=5+9=6+8,\ 20=9+11=8+12,\ 21=10+11,$$

we must have the following number pairs drawn:

$$4=1+3,\ 6=2+4,\ 13=6+7,\ 14=5+9,\ 20=8+12,\ 21=10+11.$$

Solutions were also offered by Rosa Jackson, Memphis, Tenn.; Felix John, Philadelphia, Pa.; J. H. Means, Austin, Texas; Rodney Phillips, San Diego, Calif.; Warren Rufus Smith, Brooklyn, N. Y.; W. R. Talbot, Jefferson City, Mo.; and H. C. Torreyson, Prospect Heights, Ill.

2759. *No correct solution has been offered.*

2760. *Proposed by W. W. Johnson, Cleveland, Ohio.*

Find the volume of the solid formed by revolving the area bounded by $y=x^4-4x^2+4$ and the x-axis about the x-axis.

Solution by W. R. Talbot, Jefferson City, Mo.

The function is symmetric about the y-axis and has x-intercepts of $1\pm\sqrt{2}$. The desired volume is

$$2\pi\int_0^{\sqrt{2}} y^3dx=2\pi\int_0^{\sqrt{2}}(x^6-8x^6-24x^4-32x^2-16)dx=2\pi\left(\frac{x^9}{9}-\frac{8x^8}{7}+\frac{24x^5}{5}-\frac{32x^3}{3}+16x\right)_0^{\sqrt{2}}$$

$$=2\pi\sqrt{2}\left(\frac{16}{9}-\frac{64}{7}+\frac{96}{5}-\frac{64}{3}+16\right)=\frac{4096\pi\sqrt{2}}{315}.$$

Solutions were also offered by Lowell Van Tassel, San Diego, Calif.; Herbert Wolf, Chicago, Ill.; and Dale Woods, Kirksville, Mo.

STUDENT HONOR ROLL

The Editor will be very happy to make special mention of classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

Editor's Note: For a time each student contributor will receive a copy of the magazine in which his name appears.

The Student Honor Roll for this issue appears below.

2758. *William Early, Thomas Hartberg, Carol Jarentowski, Richard Nordost, Margaret Staudenmaier, Anthony Zahorik, students at Catholic Central High School, Marinette, Wis.*

2758. *H. R. Leifer's 4th Period Physical Science Class, Allegheny High School, Pittsburgh, Pa.*

2759, 2760. *Robert N. Cahn, Atherton High School, Atherton, Calif.*

2760. *Floyd D. Wilder, Bethany Nazarene College, Bethany, Okla.*

PROBLEMS AND SOLUTIONS

2779. *Proposed by H. C. Torreyson, Prospect Heights, Ill.*

A math student stopped at the book store and inquired the price of a certain book. He was told that the price of the book with the standard hard cover was \$1.60; with deluxe cover, \$2.00; and with paper back, \$.90.

"Which do most students buy?," he asked.

"We have sold the last 100 copies for \$100," he was told, "figure it out for yourself."

How many copies of each were included in the 100 copies?

2780. *Proposed by D. Moody Bailey, Princeton, W. Va.*

The incircle of triangle ABC touches sides BC, CA, and AB at points M, N, and O respectively. P is any point on NO through which rays from B and C are drawn. BP meets CA at E and CP meets AB at F. Show that EF is tangent to the incircle of triangle ABC for all positions of point P on NO.

2781. *Proposed by Walter H. Carnahan, Madison, Wis.*

Find the smallest pair of consecutive even integers each of which is the sum of two cubes.

2782. *Proposed by Felix John, Philadelphia, Pa.*

Let $N, N+1, N+2, \cdots, N+999{,}998, N+9999{,}999$, be 1,000,000 consecutive positive integers each of which has a square factor. What is the lowest possible value of N?

2783. *Taken from "More Problematical Recreations"*

At a party there are: 14 girls, 11 adults without costumes, 14 women, 10 girls

with costumes, 24 people without costumes, 8 women with costumes and 10 males with costumes. How many people are at the party?

2784. *Proposed by G. P. Speck, Virginia, Minn.*

In the August 1959 issue of the *Scientific American* the interesting irrational number ϕ is considered in connection with the additive Fibonacci sequence: 1, 1, 2, 3, 5, 8, 13, 21, 34, · · · . It is stated that

$$\lim_{n\to\infty} \frac{A_{n+1}}{A_n} = \phi = \frac{1+\sqrt{5}}{2}.$$

Prove this.

Books and Teaching Aids Received

Biology

STYLE MANUAL FOR BIOLOGICAL JOURNALS, prepared by the Committee on form and Style of the Conference of Biological Editors. Cloth. 15×23 cm. 92 pages. 1961. American Institute of Biological Sciences, 2000 P Street, N. W., Washington 6, D. C.

Elementary Science

ABC SCIENCE SERIES, by Willard J. Jacobson and Cecilia J. Lauby. All cloth. All 15.5×23 cm. 1961. American Book Company, 55 Fifth Ave., New York 3, N. Y.

Book One. 153 pages. Price $2.24.
Book Three. 233 pages. Price $2.68.
Book Five. 346 pages. Price $2.92.

CURRICULUM FOUNDATION SERIES, by Wilbur Beauchamp. All cloth. All 23×17.5 cm. 1961. Scott, Foresman and Company, 433 East Erie Street, Chicago 11, Illinois.

SCIENCE IS LEARNING. 128 pages. Price $2.44.
SCIENCE IS LEARNING (Teacher's Edition) 128+92 pages. 19×35.5 cm.
SCIENCE IS FUN. 112 pages. Price $2.20.
SCIENCE IS EXPLORING. 168 pages. $2.68.

General Science

SCIENCE IN TODAY'S WORLD SERIES, by Maurice U. Ames, *Assistant Superintendent of Schools, New York City*, Authur O. Baker, *Cleveland Board of Education*, and Joseph F. Leahy, *John Marshall High School*. All Cloth. All 16×23 cm. 1961. Prentice-Hall, Inc. Englewood Cliffs, N. J.

SCIENCE IN TODAY'S WORLD. 416 pages. Price $3.96.
SCIENCE FOR YOUR NEEDS, 430 pages. Price $4.12.
SCIENCE FOR PROGRESS. 610 pages. Price $5.24.

Mathematics, Miscellaneous

AN ELEMENTARY TREATISE ON CURVE TRACING, by Percival Frost, Sc.D., F.R.S., *Formerly Fellow of St. John's College, Cambridge*. Cloth. 12.5×20.5 cm. 210 pages. 1961. Chelsea Publishing Company, 50 E. Fordham Road, N. Y. 68, N. Y.

A TREATISE ON THE HIGHER PLANE CURVES, by George Salmon, *D.D., D.C.L., LL.D., F.R.S. Regius Professor of Divinity in the University of Dublin*. Cloth. 12.5×20.5 cm. 395 pages. 1961. Chelsea Publishing Company, 50 E. Fordham Road, N. Y. 68, N. Y.

THE LANGUAGE OF MATHEMATICS, by Frank Land. Cloth. 17.5×25 cm. 264 pages. 1961. John Murray, Fifty Albemarle Street, London, England.

Physics

THE NEW AGE IN PHYSICS, by Harrie Massey. Cloth. 21×13.5 cm. 342 pages. 1961. Harper & Brothers Publishers, 49 East 33D Street, New York 16, N. Y. Price $4.25.

INTERNATIONAL EDUCATION IN PHYSICS, by Sanborn C. Brown and Norman Clarke. Cloth. 14×22.5 cm. Pages xvi+191. 1961. John Wiley & Sons, Inc. 440 Fourth Avenue, New York 16, N. Y. Price $4.50.

Secondary Mathematics

ESSENTIAL MATHEMATICS, by Francis G. Lankford, Jr., James F. Ulrich, and John R. Clark. Cloth. 15×23 cm. Pages viii+536. 1911. World Book Company, Tarrytown-on-Hudson, New York, N. Y.

MODERN TRIGONOMETRY, by Dick Wick Hall & Louis O. Kattsoff. Cloth. 14×22.5 cm. 236 pages. 1961. John Wiley & Sons. Inc. 440 Fourth Avenue, New York 16, N. Y. Price $4.95.

MATHEMATICS IN DAILY USE, by Walter W. Hart, Veryl Schult, and Lee Irvin. Cloth. 14×23.5 cm. Pages ix+374. 1961. D. C. Heath and Company, 285 Columbus Ave., Boston 16, Massachusetts. Price $4.20.

MODERN FUNDAMENTALS OF ALGEBRA AND TRIGONOMETRY, by Henry Sharp, Jr. Cloth. 15×23 cm. Pages ix+340. 1961. Prentice-Hall, Inc., Inglewood Cliffs, N. J. Price $8.65 (trade edition) and $6.50 (classroom adoption).

FIRST COURSE IN ALGEBRA, by Arthur W. Weeks and Jackson B. Adkins. Cloth. 13.5×23 cm. 534 pages. 1961. Ginn and Company, Statler Building, Boston 17, Massachusetts. Price $4.40.

Science, Miscellaneous

HENDERSON'S DICTIONARY OF SCIENTIFIC TERMS, by John H. Kenneth. Cloth. 13.5×22 cm. Pages xv+595. 1961. D. Van Nostrand Company, Inc., Princeton, N. J. Price $12.50.

SCIENCE IN GENERAL EDUCATION, by Robert Ray Haun, *Drake University*. Cloth. 15×23 cm. Pages x+291. 1961. Wm. C. Brown Company, Dubuque, Iowa. Price $4.50.

Miscellaneous

THE WELLSPRINGS OF LIFE, by Isaac Asimov. Paper. 10×18 cm. 1961. 200 pages. The New American Library of World Literature, Inc., 501 Madison Ave., New York 22, N. Y. Price $.50.

STUDY ABROAD. by Irwin Abrams and W. R. Hatch. Paper. 14×23.5 cm. 21 pages. U. S. Department of Health, Education, and Welfare. Office of Education. Washington, D. C.

WEATHER MAPS SENT BY RADIO FROM METEOR TRAILS

Weather maps have been successfully transmitted over distances up to 900 miles by bouncing radio signals off meteor trails. Radio communication by meteor trails is one possibility of overcoming disturbances in the ionosphere, affecting radio communications.

Book Reviews

SMITH'S COLLEGE CHEMISTRY, 7th Edition, by William F. Ehret, *New York University*. Cloth. Pages viii+947+xiii. 23.5×15.5 cm. 1960. Appleton-Century-Crofts, Inc., 35 West 32nd Street, New York 1, New York. Price $7.75.

This is the seventh revision of a textbook which first appeared in 1906 with Alexander Smith as author. He was a professor of chemistry at Chicago University and later at Columbia University. This original textbool set the pace for around 50 years of college chemistry teaching.

I think it would be fair to say that most general college chemistry textbooks from 1910 up through around 1948 were patterned to a large extent along the Smith's college chemistry lines. Much of this time, Smith's college chemistry was the leading textbook for a general college chemistry course. After Dr. Smith's death, around 1920, the third, fourth, and fifth editions were revised by James Kendall, who is now head of the Chemistry Department at Edinburgh University. William Ehret was responsible for not only this edition but also the sixth edition. The author of this seventh edition has kept the Smith approach which put great emphasis on the definition of all scientific words used in the text as well as on the descriptive chemistry approach. In the preface the author states: "It has been the endeavor of the author to have this, the seventh edition, follow the same course (as the sixth edition) and continue to give a clear, interesting, and authoritative treatment of the foundamental principles of chemistry." To achieve this end there has been a reorganization of subject matter: "(1) the introduction of atomic structure at an earlier point in the text than previously; (2) the treatment of the theoretical, unifying concepts of the subject in the first half of the book and the elements, by periodic groups in the second half; and (3) the reservation of the more specialized subjects—electrochemistry, organic compounds, and transmutation—until the end of the book."

The author has also made some use of the structural approach, similar to that found in the texts by Linus Pauling. By this latter approach we refer to the much greater emphasis placed upon the correlation between chemical and physical properties and what is known about the electronic structure of matter.

This reviewer has through the years studied and successfully taught the various editions of Smith's college text to college freshmen. Many of these students have gone on to graduate schools and, in turn, have become leading chemists in America.

A hasty review leads the reviewer to believe that we again have an excellent up-to-date college text which will find a wide adoption. By way of comparison with the sixth edition, he would like to say that the seventh edition is presented in much better form—better paper, better print, better illustrations and better bound. At the end of each chapter there may be found a good set of thought provoking exercises. The older sixth edition had a double columnn format while this one has the single column format. The reviewer regrets the fact that the author did not imitate his sixth edition and give at the end of each chapter a list of journal references. Some may object to the size of the book since it contains over 900 pages. However, it is clearly written and a teacher could easily select material in such a way as to teach a very instructive and worthwhile course.

GERALD OSBORN
Western Michigan University

SINCE 1931 **SCIENCE FILMSTRIPS** SINCE 1931
MADE BY TEACHERS FOR TEACHERS
BIOLOGY • HEALTH & SAFETY • PHYSICS • GENERAL SCIENCE
CHEMISTRY • ATOMIC ENERGY • MICROBIOLOGY
Get the Fundamentals FIRST
Box 599SSM **VISUAL SCIENCES** Suffern, New York

The McGraw-Hill

ENCYCLOPEDIA of SCIENCE and TECHNOLOGY

A NEW STANDARD—

VALUE

High school students studying biology, chemistry, physics, the earth sciences, physiology, and astronomy, plus advanced placement courses and technical and advanced vocational courses, will find *The Encyclopedia of Science and Technology* of lasting use.

SCOPE

The Encyclopedia of Science and Technology fulfills a prime need for an up-to-date source of scientific reference covering a vast fund of knowledge with hundreds upon hundreds of subjects dealing with the whole spectrum of the life, earth, and physical sciences. This encyclopedia brings the student as close to authentic information as his classroom, laboratory, or library. The articles range from concise definitions to amazingly comprehensive treatments of numerous scientific areas. In short, nothing comparable in breadth of conception, in authority, in usefulness, has ever before been offered in a reference work of this kind.

SCHOLARSHIP

An unsurpassed 15 volume scientific encyclopedia . . . Over 2,000 outstanding specialists, including Nobel Prize Winners, present the basic concepts, terminology, and newest findings in the expanding world of science and engineering . . . Over 7,200 comprehensive articles . . . 9,700 maps, charts, diagrams, drawings and photographs . . .

Regular Edition: $195.00

Leather Bound: $285.00

(Subject to usual school discount)

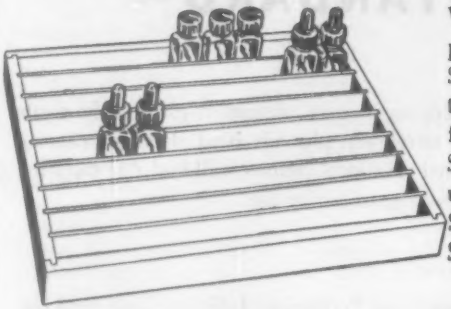
A YEARBOOK OF SCIENCE keeps the encyclopedia an indispensable reference source.

APPROVED for purchase under the terms of Title III, NDEA.

School Department • **McGRAW-HILL BOOK CO.**

NEW YORK CHICAGO DALLAS CORTE MADERA, CALIF.

WACO SEMI-MICRO APPARATUS



Wilkens-Anderson has earned its place as specialist in Apparatus for Semi-Micro chemistry . . . through the years authors have looked to us for the pieces which made their Semi-Micro text books and manuals so successful and easy to use! Seven text books now show WACO S-M apparatus!

WEISBRUCH-WACO Reagent Bottle Tray

According to SEMI-MICRO LABORATORY EXERCISES In High School Chemistry, by Fred T. Weisbruch.

Holds complete set of student reagents in WACO Reagent Bottles, in rows. Made of hard maple and birch, a permanent piece used many years. Size 12 x 10½ x 1¼ inches. Without bottles, $3.25 each . . . in dozen lots $2.95 each. Specify Cat. No. S-10490-1.

HAND FINISHED SPATULAS

Perfectly shaped spatulas for Semi Micro Qualitative and Organic Chemistry. W A C O Monel Spatulas are nicely balanced, permanent pieces. Glassware breakage is reduced, as scratching is eliminated. No. S-10115 WACO Monel Spatulas 175 mm. long. Slightly dished tip to hold crystals. $3.10 per doz., $24.00 per 100.

At the price, W A C O Spatulas class as "Non-Returnables!"

Write today for FREE brochures . . .

- Complete Catalogue WACO Semimicro Apparatus, Vol. S-1.
- Listing of S-M Apparatus according to SEMI-MICRO LABORATORY EXERCISES In High School Chemistry, Fred T. Weisbruch.

Semi Micro

LABORATORY SUPPLIES AND CHEMICALS

WILKENS-ANDERSON CO.

4525 W. DIVISION ST., CHICAGO 51, ILLINOIS

The Human Equation

SNAPSHOTS FROM ALGEBRA'S HISTORY

Burned Books and Buried Scholars

"You have heard of the Great Wall of China. Have you heard of the emperor who used it as a concentration camp for scholars? His name was Shii Huang-ti, and he came to the throne in 221 B.C.

"Shii Huang-ti had delusions of grandeur. He was determined to be remembered as the greatest of all emperors. Among other things he wanted to be famous as the ruler in whose reign knowledge increased beyond measure.

"He took a strange way to get this last wish. He ordered all books on certain topics—including all books on mathematics and related subjects—to be burned! Apparently he reasoned this way: 'If in years to come, there is no mathematics book in all China that was written before my reign, but many books written during my reign, then people will think that mathematics began with me.'

"Shii Huang-ti knew that scholars did not willingly burn books, so he fixed a penalty for failure to obey his orders: branding and four years hard labor on the Great Wall. Even so, 460 scholars banded together to defy the emperor. But Shii Huang-ti was more powerful than they: he had them buried alive.

"So the books were burned. And the emperor called for new books. Of course, new books were written. Mathematicians who were neither slaving on the Wall nor buried in the sod worked feverishly to record their knowledge for the use of future generations. One of the books they rewrote is called *Arithmetic in Nine Sections*. There is reason to believe that this book was originally written before 1000 B.C. It is more algebra than arithmetic; it includes many topics that you will study this year and some that are more advanced than a first year course in algebra."

Excerpt from ***Algebra for Problem Solving,*** Book I
by Freilich, Berman, Johnson

Algebra for Problem Solving recognizes and provides for "the human element" in its effective and thorough course of study. The illustrated two book series offers chapter summaries, tests, and reviews in a complete evaluative program that is useful for teachers.

ALGEBRA FOR PROBLEM SOLVING Book I and Book II
Freilich • Berman • Johnson

HOUGHTON MIFFLIN COMPANY Publishers

Regional Sales Offices: New York 16 Atlanta 5 Geneva, Ill. Dallas 1 Palo Alto

WILEY BOOKS

PLANETS, STARS, and GALAXIES

By STUART J. INGLIS, *Contra Costa College.* The purpose of this book is to present the subject of astronomy to those students who, though not well grounded in mathematics, want to understand the physical universe. It has been written in the belief that, in this so-called "space age", astronomy has a special fascination even for students who are not primarily interested in the natural sciences. *Planets, Stars, and Galaxies* has been specifically designed to maintain and further stimulate the student's interest in the physical universe. As an examination of the book will clearly demonstrate, the author is a man who knows how to write and how to develop his subject in a manner that is lucid, stimulating, and scientifically accurate. Thus, the exposition is not broken up into unrelated sections and sub-sections; rather it proceeds logically and coherently from paragraph to paragraph and from chapter to chapter, developing each new topic from those immediately preceding and relating the various aspects of astronomical science to one another.

1961. 474 pages. Illus. $6.75.

ELEMENTARY ALGEBRA for COLLEGE STUDENTS

By IRVING DROOYAN, *and* WILLIAM WOOTON, *both of Pierce College.* This textbook has been written for students who are beginning their study of algebra at the college level and who are scheduled to complete two semesters of high school work in one semester. For those students who are not particularly mathematically oriented and do not have a high mathematical aptitude, this book should be especially effective for the following reasons: the approach is intuitive; arithmetical ideas are used as an introduction to algebraic concepts; the textual discussions are brief and to the point; a large number of sample problems are offered; the line graph is introduced early in the book and used as a base for the concept of order; the material is continually reviewed by means of chapter reviews and a total of 18 cumulative reviews; and a glossary of terms is included.

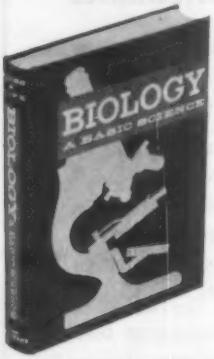
The general organization and content of the book is traditional. However, the authors employ a modern means of treating the variable and they present the equation as a symbolic sentence. The chapter on graphing is presented from the standpoint of ordered pairs—a modern and essentially clearer means of doing this than the traditional method permits.

1961. 272 pages. Illus. $4.95.

JOHN WILEY & SONS, Inc.

440 Park Avenue South, New York 16, N. Y.

3 important new science texts



BIOLOGY: A Basic Science

Heiss and Lape ***1961 edition***

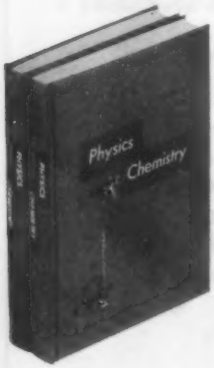
The 1961 edition of the popular Heiss and Lape text takes your students to the threshold of the future. Fascinating new chapters explore the special problems posed by the use of nuclear energy and by space travel. Using the problem approach, the authors teach the basic facts, concepts, and principles of biology as a vital force in our daily lives. More than 400 illustrations, nearly half in color, emphasize key facts and principles.

EARTH SCIENCE

The World We Live In

Namowitz and Stone ***1960 edition***

The undisputed leader among high school earth science texts! More than 50,000 copies sold in 1960! Enthusiastically and universally acclaimed: "packed with factual data" (*The Mineralogist*); "one of the best, if not the best, book on the overall story of the earth . . . a complete, yet easy to read book" (*Gems and Minerals*); "copiously and beautifully illustrated" (*New York State Education*).



PHYSICS AND CHEMISTRY

A Unified Approach

Hogg, Bickel, and Little ***1960-1961***

This revolutionary two-volume text for a two-year combined course in physics and chemistry has been thoroughly tested over a period of several years. This new approach takes full advantage of the underlying unity of two sciences, leading the students to a far more thorough knowledge and understanding than they could obtain from the conventional separate courses. Book One—available. Book Two—Summer, 1961.

D. Van Nostrand Company, Inc.

120 Alexander Street Princeton, New Jersey

Please Mention *School Science and Mathematics* when answering Advertisements

APTITUDE AND ACHIEVEMENT TESTS
for
SCIENCE AND MATHEMATICS

General Science	General Mathematics
Biology	Arithmetic
Chemistry	Algebra
Physics	Geometry

Standardized—Quick-Scoring

Write for catalog and prices

BUREAU OF EDUCATIONAL RESEARCH AND SERVICE
EXTENSION DIVISION, STATE UNIVERSITY OF IOWA, IOWA CITY

School Science *and* Mathematics

will keep you in touch with the most recent advances in scientific knowledge and teaching methods.

Classroom helps and special teaching devices for difficult topics are regular features. The Problem Department gives inspiration and extra activities for superior students.

The most progressive teachers in schools and colleges all over the world are regular readers and many of them are frequent contributors to this Journal.

School Science and Mathematics
P.O. Box 108, Bluffton, Ohio

NEW EDITIONS!

Algebra, First Course, 2nd Edition
Algebra, Second Course, 2nd Edition

by John R. Mayor and Marie S. Wilcox

With its fresh approach, the First Course makes algebra interesting to the student and is adaptable for pupils of every aptitude. The Second Course continues this careful, systematic development, and provides additional preparation for advanced work in science and math.

For further information write to:

PRENTICE-HALL, INC.
Educational Book Division, Englewood Cliffs, N.J.

for 1961 . . . when the teaching of
science and mathematics is in the national spotlight . . .

MODERN SPACE SCIENCE

by Trinklein and Huffer

A high school course which deals with a science which is most relevant and exciting to today's teen-agers, Modern Space Science:

- Gives youth an understanding of the problems of space science
- Presents extensive and logical treatment of the discoveries and principles upon which the conquest of space is built
- Draws upon the various branches of science to tell the story of space as a unified and intelligible sequence

CONTEMPORARY ALGEBRA AND TRIGONOMETRY

by Griswold, Keedy, and Schacht

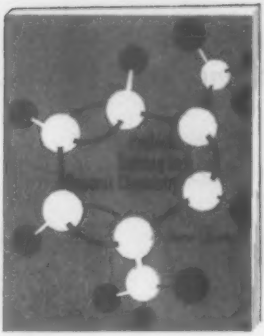
Focusing on the contemporary objectives of developing mathematical ability to innovate, create, and formulate, this textbook:

- Integrates algebra and trigonometry through a modern concept of trigonometric functions and algebraic development
- Stimulates students to explore mathematical structure and gain insight into the various number systems
- Promotes real understanding of the structure, precise language, and logical procedures of mathematics

HOLT, RINEHART AND WINSTON, INC.

383 Madison Avenue
New York 17, N. Y.

536 Mission Street
San Francisco 5, Calif.



To help your student "see through" and solve chemistry problems on his own

Problem Solving in General Chemistry

by George I. Sackheim

- *Provides the high school student with groundwork in the mathematics of chemistry.*
- *Offers complete step-by-step instruction on how to solve chemistry problems.*
- *Makes a clear explanation of concepts that are the most difficult for students.*
- *Contains over 1100 examples and problems for the student to solve.*
- *Develops the ability to "think-through" problems rather than rely solely on memorizing mathematical formulas.*

Here is a book that students in general chemistry will find invaluable for learning to make chemical calculations. With vigor, clarity and thoroughness, it shows how to solve a chemical problem; and it explains all the important concepts such as atomic structure, valence, nomenclature, and others.

Among its significant features is the General Mathematical Review found in Chapter 1. This chapter covers areas that serve as a springboard to a sound understanding of the mathematics of chemistry. The book is complete with necessary tables and charts. And answers to all problems are contained in a separate 16-page Answer Book available to teachers on request.

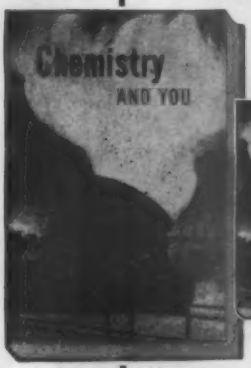
Row, Peterson and Co.

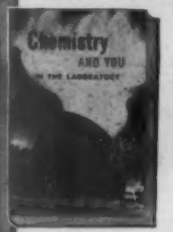
Evanston, Illinois **Elmsford, New York**

Please Mention *School Science and Mathematics* when answering Advertisements

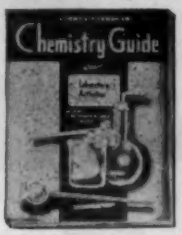
Here is today's most COLORFUL and OUTSTANDING text

and here also are three other popular high-school books from our chemistry family.

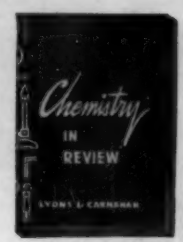




For use with any text



Study Guide and Manual with tests



Review Book or short text

LYONS & CARNAHAN

2500 PRAIRIE AVENUE • CHICAGO 16, ILL.

The Chemical Elements and Their Isotopes

by GILBERT GORDON, *University of Chicago*

A 38 page booklet in which the isotopes of the chemical elements are described and tabulated. The booklet discusses the properties of the elements which allows them to be placed into unique positions in the periodic table. "Isotopes" and "Radioactivity" are also explained in the beginning of the booklet. The tables contain 975 isotopes of the 103 elements. The following information is compiled in the tables: Atomic weight, % occurrence, type of radiation, and the half-life of the isotopes. A periodic table and a fold-out chart which graphically displays the Parent and Daughter products of the four radioactive series is also included.

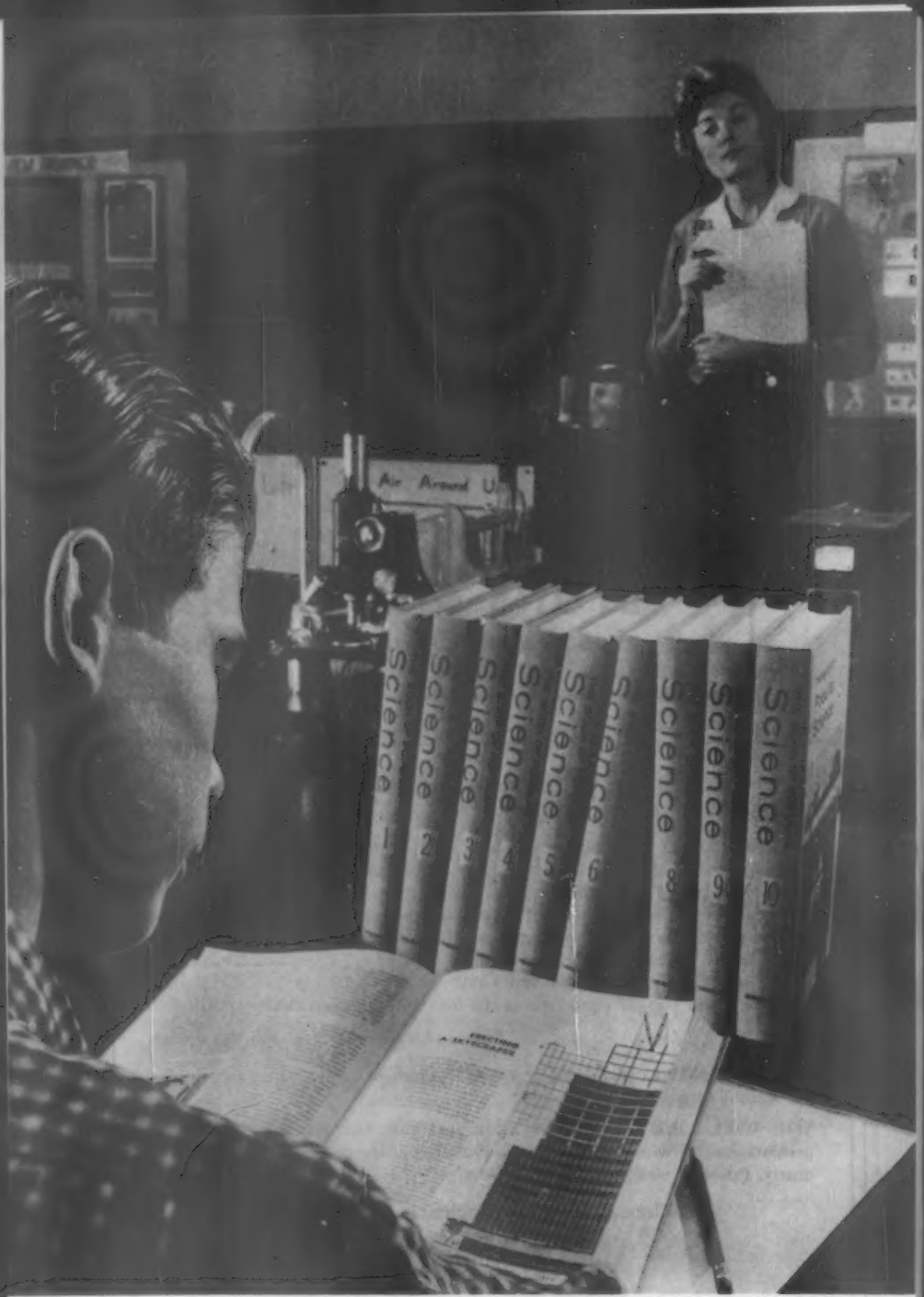
Price 95¢ each plus 10¢ Mailing Charge

TREE OF KNOWLEDGE—27¾ × 21" Wall Chart in Color. Price 75¢ each plus 20¢ Mailing Charge.

YOU WILL LIKE GEOMETRY. Illustrated pamphlet giving comprehensive presentations of the Mathematics exhibit at the Museum of Science and Industry. Price 15¢ each plus 5¢ Mailing charge.

Address: **Museum of Science and Industry**
57th & South Shore Drive
Chicago 37, Illinois

PLEASE REMIT MONEY WITH ORDER



THE BOOK OF POPULAR SCIENCE IS THE ONLY GENERAL PURPOSE SCIENCE REFERENCE WORK FOR GRADES SIX THROUGH TWELVE

**The Book of Popular Science is double-starred in the AAAS Science Book List; it qualifies for purchase under Title III NDEA

Published by The Grolier Society Inc. • 575 Lexington Avenue, New York 22, N. Y. • Publishers of The Book of Knowledge

MATHEMATICS TEXTS FOR TODAY— WITH TOMORROW IN MIND

coming this month:

GEOMETRY

by Howard F. Fehr and Walter H. Carnahan

A new geometry, designed for college-bound students who have had elementary algebra. The book presents the standard Euclidean plane geometry from a contemporary point of view with integrated topics in coordinate and solid geometry. Provision is made for individual differences in ability so that the more able student has ample stimulation and challenge and the slower student sufficient practice work.

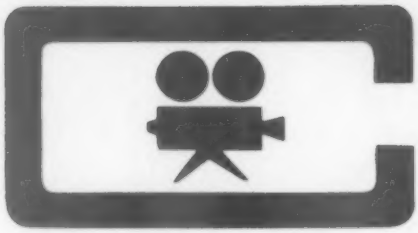
published in January:

MATHEMATICS IN DAILY USE, 3RD EDITION, REVISED

by Walter W. Hart, Veryl Schult, and Lee Irvin

Motivation is built-in because the problems in the text are very practical and obviously useful. Arithmetic processes are taught inductively and taught thoroughly; abundant practice material is provided; new concepts and skills are used immediately after they are introduced. Here, too, is information on the fundamentals of banking, taxes, insurance, and simple business transactions that concern everybody. An interesting format with engaging illustrations attracts pupils at once.

D. C. HEATH AND COMPANY



CENCO EDUCATIONAL FILMS

NEW SCIENTIFIC AUDIO-VISUAL MATERIALS FOR ELEMENTARY AND SECONDARY SCHOOLS.

Keeping pace with the rapidly expanding field of education, Central Scientific Company announces the formation of a new motion picture production unit, Cenco Educational Films. David Wisner has been named Executive Producer, heading up the organization.

For over seventy years, Cenco has been a major producer of scientific apparatus and has pioneered in the development of quality equipment for both classroom and industry. Working in collaboration with the nation's leading educators, Cenco now enters another field, motion picture and filmstrip production.

Available currently are two series of films in 16mm color, a single feature film in 16mm color and a number of filmstrips. In production are series on Nuclear Radiation, Heat and Cold, and Plane Geometry.

Information on these films can be obtained through your local Cenco sales representative, or write requesting placement on a special mailing list for the 500-series Audio-Visual Booklet.

CENCO EDUCATIONAL FILMS

A Division of Cenco Instruments Corporation

1718-L Irving Park Road • Chicago 13, Illinois

Mountainside, N. J. Montreal Santa Clara
Somerville, Mass. Toronto Los Angeles
Birmingham, Ala. Ottawa Vancouver Houston
Cenco S.A., Breda, The Netherlands Tulsa